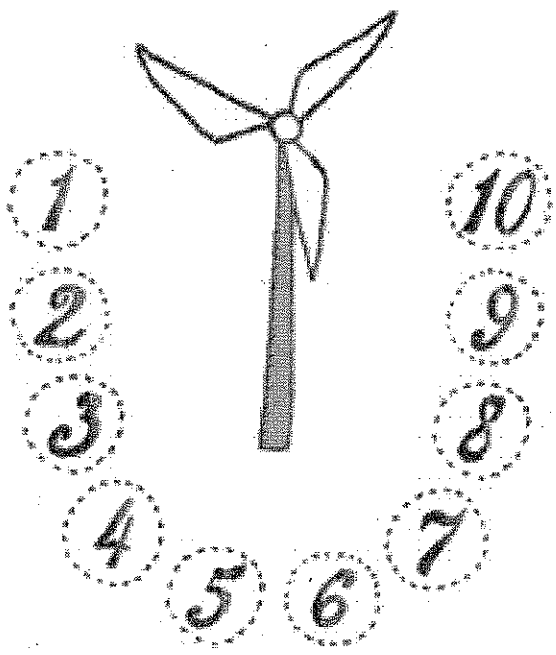
Wind Turbine Syndrome for Non-Clinicians

Abstract

I interviewed 10 families living near large (1.5 to 3 MW) wind turbines, all of which were built since 2004. This gave me 38 people, from infants to age 75. Their symptoms formed a cluster (see Glossary for clinical terms):



1) sleep disturbance
2) headache
3) tinnitus (pronounced "tin´-ah-tus": ringing or buzzing in the ears)
4) ear pressure
5) dizziness (a general term that includes vertigo, lightheadedness, sensation of almost fainting, etc.)
6) vertigo (clinically, vertigo refers to the sensation of spinning, or the room moving)
7) nausea
8) visual blurring
9) tachycardia (rapid heart rate)
10) irritability
11) problems with concentration and memory
12) panic episodes associated with sensations of internal pulsation or quivering, which arise while awake or asleep

The families not only lived near turbines and developed new symptoms; they moved away from the turbines (because they were so troubled, often abandoning their homes) and the symptoms, significantly, went away.

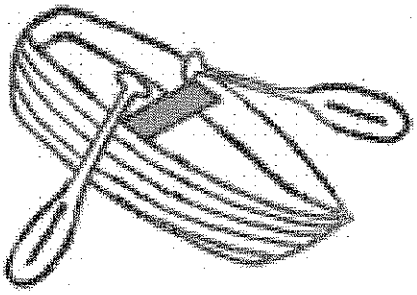
Hence, the definitive result of my report is that wind turbines cause the symptoms of Wind Turbine Syndrome (WTS).

Let's clarify something immediately. Not everyone living near turbines gets these symptoms. As a solo, unfunded researcher I could not get the samples needed to figure out what percentages of people at what distances get the symptoms. This needs to be done next. But I could (and did) look at the question of why some people are susceptible and others not, plus who is susceptible, and I used these patterns to explore the pathophysiology of Wind Turbine Syndrome: what's going on inside people to cause these specific symptoms.

I would like readers to be able to look at this study—including the detailed accounts I provide of people's experiences around turbines and their health backgrounds—and be able to make their own decisions about whether they should be exposed to these machines.

That said, I was able to prove mathematically that people with pre-existing migraines, motion sensitivity (such as car-sickness or seasickness), or inner ear damage are especially vulnerable to these symptoms. Equally as interesting, I was able to demonstrate that people with anxiety or other preexisting mental health problems are not especially susceptible to these symptoms.

This contradicts wind industry literature, which argues that people who worry about or otherwise dislike turbines ringing their homes are the ones getting ill. I show this to be complete nonsense.



Here is what's going on, as I put together the evidence. *Low frequency noise tricks the body's balance system into thinking it's moving.* Like seasickness. (It's vital to understand that the human balance system is a complex brain system receiving nerve signals from the inner ear, eyes, muscles and joints, and inside the chest and abdomen. Because the eyes are involved, visual disturbance from the blades' shadow flicker adds to the balance disturbance.)

Let me repeat this, because its significance is huge. *Low frequency noise from turbines appears to deceive the body into thinking it's moving.* So what, you say? Not so fast! Research within the last 10 years has demonstrated conclusively that *the way our bodies register balance and motion directly affects an astonishing array of brain functions.*

How? By direct neurologic linkages connecting the organs of balance to various, seemingly unrelated brain functions.

I'll rephrase this, since it's critical to the argument of this report. *The way our bodies perceive balance and motion in turn influences a host of brain functions which at first glance might appear to be entirely unrelated to balance and motion.* As I said, this is what the latest "balance" research tells us—more accurately, balance research combined with psychiatric, neurologic and cognitive research.

Incidentally, the people specializing in this kind of research are called *neuro-otologists*—from *neuro* for brain, and *oto* for ear.

And what are these seemingly unrelated brain functions affected by our perception of balance and motion?

a) *Alerting and awakening*

b) *Memory*

c) *Spatial processing.* Spatial processing is defined as the ability to 1) picture things, 2) remember where things are, 3) remember how to get somewhere, 4) understand how things work, 5) figure out how to put something together or fix it, 6) figure out the most efficient order and timing of something (such as work around the kitchen, farm, fishing boat, property, or a series of errands), 7) remember what you're looking for when you get someplace (such as errands in town), 8) understand math concepts, 9) along with a host of other critical thinking functions.

d) *The physiologic manifestations of fear.* This means increased heart rate and blood pressure, sweating, nausea, and hyper-alertness.

e) *Aversive learning.* This is when something bad happens and as a result of the experience you now know to avoid the situation in future. The classic illustration in both animals and people comes from vomiting after you eat something. You avoid that food afterwards for a long time. (Remember that experience as a child?) Aversive learning is so imprinted on mammals (we are mammals) that even the environment associated with this experience can trigger the feelings of nausea—to continue the nausea illustration. Merely smelling that particular food, or being in the same restaurant, or just thinking about that particular food, or seeing the food—makes you queasy. Aversive learning is potent and, clearly, an evolutionarily old reflex in mammals.

Okay. *Alerting and awakening, memory, spatial processing,* the *physiological manifestations of fear,* and *aversive learning.* All five brain functions are profoundly affected by our sense of balance and motion. All five get messed up when our sense of balance and motion is thrown off.

Back to wind turbines. Open any online newspaper article discussing Wind Turbine Syndrome and you almost invariably discover that someone has posted a comment ridiculing the whole idea for the obvious reason that there's no conceivable way such a disparate range of health problems—memory deficits, spatial processing deficits, anxiety and fear and panic, and aversive learning—could possibly be triggered by a wind turbine, of all things. Clearly, continues our brilliant curbside commentator, people who live near turbines and report these symptoms are making them up (probably because they don't like the darn things), and just as clearly the doctor who takes these seriously (that would be me) is a fake.

To which I respond: Clearly the authors of these brilliant gems of logic (forgive my cynicism) are neither neurobiologists nor clinicians—nor are they experiencing the symptoms which are clearly, unambiguously reported by many people living in the shadow (as it were) of industrial wind turbines.

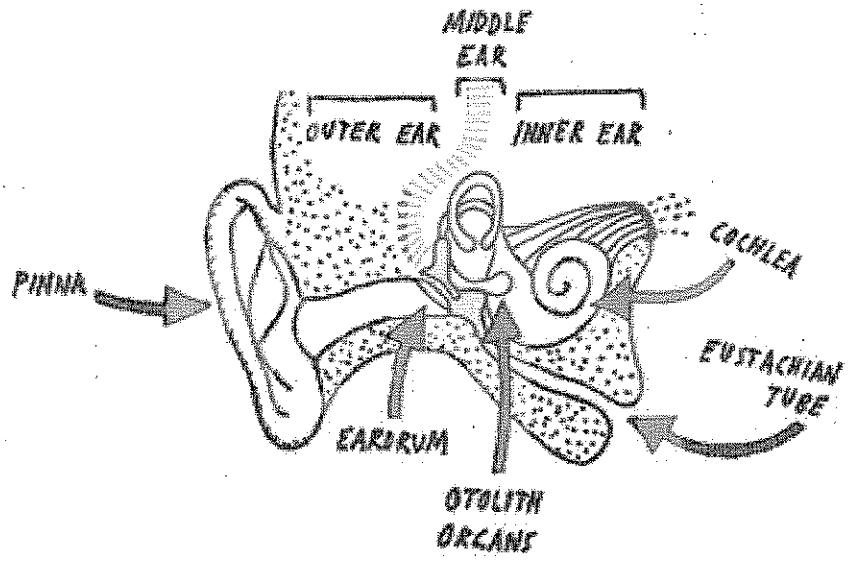
Back to real medicine. Wind Turbine Syndrome symptoms, outlined above, occur together *because humans are hardwired to exhibit these precise symptoms when their balance and motion sensors are dis-regulated*—as happens to many people living near wind turbines.

It's important to emphasize these symptoms are not psychological (as if people are fabricating them); they are neurological. People have no control whatsoever over their response to the turbines. It happens automatically. One can't turn on and turn off these symptoms.

We can be emphatic about this because *balance signals* (called *vestibular* signals) *are the one kind of sensory signal we simply cannot tune out.* You can tune out (ignore) what you see and hear—but not what comes in from your sense of balance. Call it a law of nature, if you like.

And what provides our sense of balance? Balance comes from a combination of signals. I'll rephrase this: balance comes from *clusters of signals from different body organs.* One source being, of course, the inner ear.

Stop. We need to review the anatomy of the inner ear, since it's essential to understanding Wind Turbine Syndrome.



Start with the weird flap of skin on the side of your head, necessary for holding up your glasses and, naturally, earrings. This is not the outer ear; it's the pinna. (Boxers get cabbage pinna.) The outer ear is where you put Q-Tips, and where your two-year old stores beads and other treasures, where earwax lives, and where water gets lodged when you shower—and you have to shake it out. The outer ear is a blind pouch ending at the eardrum, sealing off the pouch at the inner end.

Then comes the middle ear: the place between the eardrum and what's called the oval window. This is the part of the ear that gets infected in little kids. (Moms, remember all those times you took Johnny to the doctor and she said, "Yup, Johnny has an ear infection." This is after Johnny woke up screaming in the night, after having a cold for three days.) The middle ear is open to the air, through the Eustachian (pronounced "U-station") tube from the back of the throat (up behind the nose). And the middle ear houses those wonderful three little bones, incus ("ink-us"), malleus ("mal-ee-us"), and stapes ("stay-peas"), that are linked in a chain. Incus, malleus, and stapes transmit the energy of the vibrating eardrum to the inner ear.

This brings us to our destination in this mini-lesson: the inner ear. The inner ear consists of the semicircular canals (which you remember from high school biology) and the so-called otolith organs (which you probably don't remember from high school biology). The otolith organs are one of the keys to understanding Wind Turbine Syndrome. They consist of two little membranous sacs which are attached to the cochlea ("coke-leah") (the spiral-shaped, membranous organ that transduces the mechanical energy of sound into neural signals) and to the semicircular canals (membranous organs

which make a semi-circle in each of the three planes of movement—vertical forward, vertical sideways, and horizontal—and transduce angular acceleration: if you nod or turn your head, they detect it).

Bear with me a moment longer; we're almost there. Embedded in the two otolith organs are—believe it or not—rocks. (Remember when your teacher accused you having rocks in your head?) Well, not really rocks; they're tiny. In fact they're microscopic stones made of calcium carbonate (yes, chalk, or clam shells). The weight of these stones allows us to detect gravity and linear acceleration, by sending signals to the brain via minute neural (nerve) hair cells.

In people predisposed to Wind Turbine Syndrome the otolith organs (utricle and saccule) are (I propose) being rocked abnormally, thus sending aberrant motion signals to the brain. Either this, or their inner ear organs in general—which are all interconnected as a "membranous labyrinth"—may be hyper-sensitive to pressure changes, such as those produced by turbines.

We're in the presence, here, of a truly ancient anatomical structure. Many millions of years old. Biologists call it the macule ("mack-ewell"), which just means the "spot." The macule is critical in fish and us, and everything in between.

The macule: the membranous structure with hair cells embedded in the membrane and the otoliths fixed on top in a protein matrix. Mother Nature loved the macule so much that she conserved it through eons of evolution. Fish use these organs to figure out, instantaneously, which way is up, just like us. Fish use the macule for detecting pressure shifts in the water, such as the waves made by nearby predators or prey, or the low frequency noise traveling over long distances from waves breaking on shorelines, thus helping them navigate during migration.

Otoliths. The macule. Very ancient. Ancient and fundamental organs of balance and motion that appear to be thrown out of whack by wind turbines, with consequences I have called Wind Turbine Syndrome.

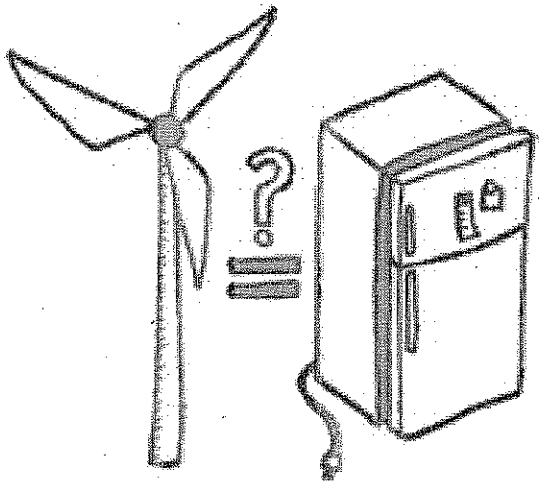
Back, now, to what provides us with our sense of balance. I said balance comes from a combination of signals, and I just explained how some of them originate in the inner ear. Besides the inner ear, the eyes also send motion and position signals to the brain. So, too, do muscles and joints all over the body, involving what are called "stretch" receptors, telling us where we are in space.

And lastly, we maintain our balance by newly discovered stretch and pressure receptors in the chest and abdomen. These tiny receptors rely on various organs, including blood vessels and blood itself, as weights to detect the body's orientation to gravity and other forms of acceleration.

All this is the proper context for studying people's health complaints from wind turbines. Health complaints that are routinely dismissed by the wind industry as nonsense. (Not unlike the tobacco industry dismissing health issues from smoking.) The wind industry, however, is not made up of clinicians, nor is it made up of people suffering from wind turbines.

In time, I hope, researchers will be able to measure and correlate wind turbine noise (audible and sub-audible) and vibration with the symptoms people experience in real time—that is, while they're actually experiencing the symptoms. Until that happens, I offer this report as a pilot study.

Introduction and Background



Developers say turbines are quiet. No louder than a household refrigerator. With this (false) claim, they easily convince local governments it's okay to erect turbines mere hundreds of feet from people's homes. Nearly in their backyards, in many instances.

Wind turbine setbacks, in other words, are wind-industry-driven. Virtually no government regulation.

This is where my phone (and email) starts ringing. People from around the world contacting me to say, often with great emotion in their voice, they haven't slept well (if at all) since the turbines were installed 1500 feet (and more) from their back door. Not just insomnia, but a host of health issues, again, since the turbines in the neighbor's field began operation.

For over four years I've been listening to their complaints. Describing symptoms that are remarkably consistent, person to person. Consistent and, often, debilitating. Symptoms, I began realizing, that suggest people's balance systems are getting messed up.

I realized what's needed is a clinical definition of the way people are getting sick when they live near wind turbines. If we can nail down the pathophysiology of their illness, we're in a better position to figure out,

a) precisely what's causing it
b) how many people are getting it
c) who is susceptible
d) how to control or prevent it.

This became my goal: figure out the pathophysiology of the illness cluster they all describe.

So let's begin. Except immediately there's a problem. Which is, developers focus on noise. They hire an acoustician to measure noise levels (incidentally, there are many ways to slice and dice noise measurements), who then writes a report saying, in effect,

a) the turbines are emitting this (whatever) dB of noise
b) the conventional acoustical wisdom about this range of dB says it doesn't create health problems
c) hence, we conclude these people are faking their symptoms
d) end of story

I turn the above sequence inside out. We need to begin with c) *symptoms*, not a) *noise levels*. The symptoms are consistent person to person, no matter if it's England or Canada or what have you. Furthermore, the symptom cluster fits with known clinical mechanisms. There is no mystery here.

Hence, the symptom cluster becomes—must become—the chief reference point.

When one measures noise, one must refine noise measurements so as to answer what it is about the noise spectrum *at this moment, when people are actually getting symptoms*, versus that other moment when they're not getting symptoms. *This* is the value of noise measurements.

Other published reports on health and wind turbines, by the way, find the identical set of symptoms to what I found. In my report I review papers by Dr. Amanda Harry, Barbara Frey and Peter Hadden, and Prof. Robyn Phipps.

a) Harry found all the same problems, and, interestingly, her group of patients was shifted toward older folks. Moreover, she sampled the same way I did: she talked to people who were bothered.
b) Frey and Hadden document the same symptoms in people's own narratives.
c) Phipps mailed questionnaires to everyone living within 9.3 miles of turbines. She got affirmative responses about unpleasant physical symptoms from people living at least 1.24 miles from turbines, on up to 2.2 miles. Some even further. Phipps got even more detail about what they were experiencing because (almost) 7% were so distressed, they telephoned her to describe more specifically their problems from turbine noise and vibration—almost all of them exhibiting disturbed sleep.

My own subjects make it clear their problems are caused by noise and vibration and, in some instances, moving blade shadows. What's more, my subjects notice that symptoms came and went with the wind's direction and strength, turbine spinning speed, which way the turbines were facing, and particular sounds coming from the turbines. In other words, they see their symptoms going up and down depending on what the turbines are doing. They also know that the quality of noise is strange and bothersome even compared to other loud noises, like nearby trains or cars. A few people were specifically bothered by the shadow flicker in rooms or blade shadows sweeping the landscape.

Above all, the symptoms went away when they left home and the turbines, and symptoms returned when they came back home.

Again, the only rational way to study the problem is *symptoms first, noise measurements second*, not the reverse.

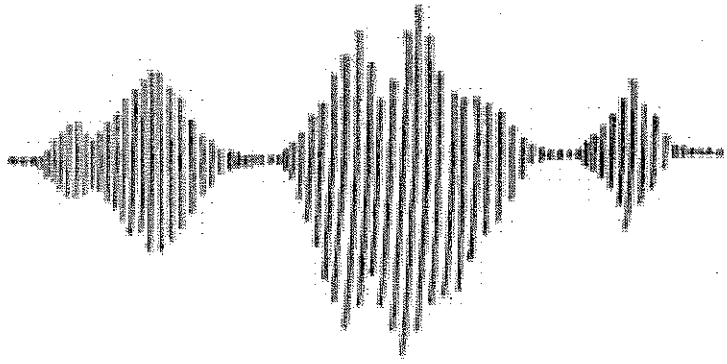
Noise. You, dear reader, need to understand what noise is before we go further. If you're confident your grasp of noise is sophisticated, then skip the next few paragraphs. Otherwise, here we go.

Wind turbines indisputably make noise from infrasonic (below what you hear), through the range you can hear (audible, in other words), to ultrasonic (above what you hear). This is well established. By "above" and "below" we mean "pitch." "Frequency" means "pitch." Hence, low frequency noise (LFN) means "low-pitched," like the low notes on a piano. High frequency means high-pitched, like the "s" sounds in human speech.

Noise also has a quality of intensity or power which, if the sound is within the hearing range, we call "loudness." Loudness or intensity is measured as "decibels" or "sound pressure level." These are both measures of how much energy, or power, is in the sound wave, and is also called "amplitude."

Next definition: wavelength. A high frequency wave means a short wavelength (as with ocean waves: when the waves arrive in rapid succession the distance between the wave peaks is short). Low frequency means a long wavelength: peaks further apart, although the waves travel at the same speed.

Now things get interesting. *A sound wave in the air is a sequence of pressure changes.* A sound wave in a solid is more like a vibration. (In fact the word "vibration" is technically used to refer only to what happens in solids.)



(As an aside, I will often talk about noise and vibration together because I'm talking about a continuum of energy as it passes through different substances. For instance, a sound wave coming through the air, hitting a building, can make the walls vibrate, which in turn sets up sound waves inside the room.)

When symptoms of the sort we're dealing with, here, have been medically studied, they are typically associated with lower sound frequency ranges—below hearing range or in the lower part of the hearing range. With further research into Wind Turbine Syndrome it may turn out that some of the turbine noise

in the higher frequencies is also causing symptoms; however, the chief noise culprit, from past clinical studies, appears to be low frequency noise.

Loudness, or intensity, also matters. How loud does a low frequency noise have to be to trigger health effects? Acousticians are taught, "*If you can't hear it, it can't hurt you!*" This, however, is an oversimplification of how the body works. Noise health standards focus on protecting people's ears from loud noise that could damage their hearing. *What these standards ignore is pressure detection by the balance mechanism or pressure or vibration effects on other parts of the body.*

There's the rub.

When we decide to look at symptoms first, the noise issue becomes very simple. People's symptoms come and go. Acousticians need to measure noise levels when symptoms are present and compare these to noise levels when symptoms are absent. In this manner they can find out exactly *what frequencies* at *what intensities* are causing symptoms.

In the *Discussion* section of my clinical report, I give two examples of published accounts by German noise control engineers correlating symptoms with their noise measurements. In each case the symptoms (very similar to Wind Turbine Syndrome, incidentally) were due to very low frequency noise. In one case the noise was identified but not the noise source; in the other case the source was a large building ventilator fan.

Back to my crash course on noise. (Yes, the pun is intended.) Resonance. Resonance is what happens inside the body of a guitar or violin after a string is plucked or disturbed by a bow. It's like an echo inside a space. Thus certain wavelengths bounce back and forth very efficiently, given the size of that space. The walls of the space tend to vibrate at particular frequencies, and if the natural vibration frequency of the wall is the same as the incoming sound frequency, the wall itself (guitar wall, violin wall) can give an added "punch" to the sound, making it louder.

This is a lot like pumping a swing. (We all did this as children.) Swinging is a kind of wave function, like sound, with frequency and amplitude. The frequency of the swing is how many times per minute it's going back and forth. Frequency depends on the length of the ropes—a short swing swings faster. Amplitude is how high the child is swinging. Resonance is a child who knows how to pump (add some

energy to the swinging) at exactly the right time to increase the amplitude (swing higher). The frequency stays the same, but, as the child pumps, she swings higher and higher.

The child pumping is like the wall of a resonant chamber; it provides a little push to the "wave" at exactly the right time.

Okay, course on noise is over. Now let's apply it to Wind Turbine Syndrome.

Resonances occur inside body spaces and in solid but flexible or elastic parts of the body, such as along the spine. Different parts of the body have different resonant frequencies. Many of these are in the low frequency range. When a sound wave or vibration hits the body, it's more likely to set up vibrations in a body part with a matching resonant frequency.

In Wind Turbine Syndrome, an important body resonance is the resonance of the chest and abdominal space. The chest wall is made of elastic muscles, bones, cartilage, tendons, and ligaments, giving the chest a natural recoil we use in breathing. We use energy to expand the chest to breathe in, but much of the force to push the air back out comes from the elastic recoil of the chest.

One of the important parts of the breathing mechanism is the diaphragm muscle at the bottom of the chest. It's dome-shaped, like the top of an egg. When you take a breath, the diaphragm flattens. As it flattens, it pulls down, thus expanding the chest space and pushing on the abdominal space. The abdominal space is very soft and flexible, the front being thin sheets of muscle, skin, and other soft tissues, without bone or cartilage. So when you breathe in, your stomach sticks out. When you relax the diaphragm muscle, it springs back to its dome shape and it pushes air out. Natural elasticity at work.

Hence, when air pressure waves enter the lung, it takes very little energy in the air pressure waves to set this very mobile system vibrating. At frequencies between 4 and 8 times per second, the diaphragm will vibrate. Frequencies 4-8 times/second are low frequency noise or infrasound, below hearing range.

Not only the diaphragm vibrates, but the entire mass of internal organs in the abdomen swing up and down with diaphragm movements. One of the largest abdominal organs, the liver, is attached to the underside of the diaphragm.

There are other places in the body with resonance, including the eyes (globes with bone around them and less dense material inside) and the brain case. Even the spine (backbone) has a resonance frequency. The spine is elastic. If it's vibrated at a particular frequency it can set up a vertical vibration along the spine.

Even very small body parts, like blood vessels inside the brain, have resonances that influence the damage caused by air pressure waves from a nearby blast, for example.

In sum, what we casually call *noise* can have a powerful impact on numerous internal structures and cavities. We will see the significance of all this in the Discussion, below.

Before moving on to the Methods section, a few words about measuring sound power and what's called "A-weighting" and "C-weighting." It's difficult to measure the loudness, or energy, of sound in consistent, reproducible ways, especially at low frequencies. A-weighted and C-weighted "networks" in sound-measuring equipment screen sound energy (i.e., loudness) according to frequency. A-weighting screens out most of the low frequency and high frequency sounds; it's biased toward what the human ear hears best. C-weighting includes more of the low frequency sounds, but not the very lowest frequencies.

It's easy to obtain standardized measuring equipment with these two weighting networks (A and C), but measuring the power of the lowest frequency sound requires expensive and specialized equipment that's not standardized among models. Nevertheless, if we are to fully understand Wind Turbine Syndrome, it's at this lowest of low frequencies that measurements must be made.

Methods

I used what's called a *case series* as my research protocol. (Remember my definition of a case series from the Preface: "*A descriptive account of a series of individuals with the same new medical problem.*")

In medical research, *case series* don't usually have control (comparison) groups. However, I added a new wrinkle to my study, based on my training in field ecology: despite not having a formal control (comparison) group, I chose subjects and arranged the way I collected information so I could create comparisons.

First, to call this a wind-turbine-associated problem at all, I compared how people were *during exposure* to how they were when *not exposed,* and I specified that "not exposed" meant both *before* and *after* living near turbines. *All my subjects saw their problems start soon after turbines went on-line near their homes, and all saw their problems go away when they were away from the turbines.*

Second, to discover medical risk factors, I compared subjects who exhibited particular symptoms more intensely, to those who did not. Then I looked at whether these differences were influenced by age, underlying health conditions, etc.

There was a third type of implicit comparison going on—to the population at large. For example, both I and Dr. Harry sampled in the same way—we interviewed affected adults—and we both wound up with samples shifted toward people in their 50's or older. This suggests that older people are more often affected, since older people are over-represented in our samples. (This makes medical sense, and also corresponds to patterns of noise complaints in other, non-wind-turbine settings).

Additionally, in my study there are more people with underlying migraine than in the general population, suggesting that people with migraine are, like older people, more susceptible.

Hence, the more elderly and migraineurs (people who get migraines) stand out in my investigations.

Now, let's consider what a standard epidemiologic study of Wind Turbine Syndrome might look like, as distinct from my *case series* approach. When a scientist sets out to perform an epidemiologic study, he (she) begins by defining two identical groups to be studied. Notice, this is *before* either group is exposed to the (supposedly) disease-causing agent. One group being the *study group*, the other the *control group*. The study group, of course, is the so-called guinea pig: the individuals about to be exposed to the potential problem, in this case wind turbines. The control group is identical in every conceivable way to the study group: by age, by sex, and (in the case of wind turbines) similar rural areas with similar occupations, etc.

Then exposure starts. In this case, the turbines are built and turned on—though only, as I said, for the study group. The researchers monitor what happens to everybody in both groups—guinea pigs, non-guinea pigs—and make comparisons and draw conclusions.

But there's a problem. A problem in what's called medical ethics. *It's unethical to design a study to expose people to something already suspected to be harmful.*

So another type of epidemiologic study, a case-control study, comes to the rescue. In a case-control study, people meeting the case definition for Wind Turbine Syndrome would be enrolled. For each case, two or three other similar people not living near turbines would also be enrolled. These are the controls. The researcher would collect the same types of data on all cases and controls, and make comparisons.

But to do this we need to know what a case is: *we need a case definition.* A case definition describes the symptoms and findings, proves there's consistency from person to person, and presents ideas or hypotheses about what causes the newly defined illness.

That is what my study has done—*created a case definition.* The next step is an epidemiologic study, *but the case definition comes first.*

Back to an epidemiologic study. A standard epidemiologic study would require several years of study, a huge research grant, and a small army of researchers. Besides this, as I explained in the Preface, the gag clauses found in wind leases and so-called Good Neighbor Agreements, plus the desire to sell one's home yet not reveal the noise toxicity and thus scuttle a potential sale, and the trickiness of community relationships—all these considerations would make an epidemiologic study highly difficult and perhaps doomed.

Nevertheless, epidemiologic studies should be undertaken. At least the attempt should be made.

My report should be seen as a necessary preliminary step to this much larger, more ambitious, more long term study. However, no government or private agency will undertake this Big Study without a preliminary project like mine—let's call it a pilot study—showing there is in fact something worth studying.

Back to my report. The problem in any clinical study is figuring out which new symptoms are due to a new exposure and which are not. In an epidemiologic study this is worked out by having parallel groups, with one group not getting exposed. Since I didn't have the resources to do such a study, I insisted that among my study subjects there be a post-exposure period—a time after exposure ended, during which the symptoms disappeared. *Wind Turbine Syndrome is defined only as those symptoms which came on*

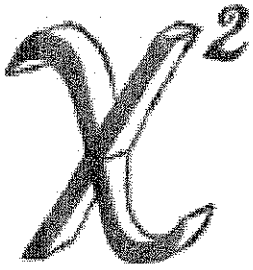
during exposure and abated only after exposure ended. It may not capture all the health effects of wind turbine exposure, because of the limitations built into my study design. But it certainly captured a significant set of symptoms.

There's an additional way I generated a comparison group. I either interviewed every family member or, in the case of a 5-year-old and the elderly senile, I got information on these people. In this way I discovered that not everyone in the family was equally affected, despite living in the same house at the same distance from the turbines. I used comparisons between affected and non-affected people to figure out which parts of their pre-exposure medical history predicted which symptoms during exposure.

With this in mind, notice how I chose my study subjects:

a) at least one family member was severely affected by living near turbines
b) the family either had to have left the home or spent sufficient time away to experience relief from symptoms
c) the people I interviewed had to be able to say clearly, consistently, and in detail what had happened to them, under what conditions and at what time
d) they all live near turbines put into operation between 2004 and 2007
e) if they had already moved out when interviewed, it was less than 6 weeks since they'd moved out
f) they had to have taken serious action to protect themselves from the turbine exposure (generally identified as noise):

    a. some moved out
    b. some purchased a second home in anticipation of moving out
    c. some left home for months
    d. one family renovated the house in an effort to mitigate the noise
    e. and one man took to sleeping in his root cellar



A final point. This squiggly symbol, χ^2, is called "chi squared" (pronounced "keye," as in "eye"). Don't panic! It's a simple statistical test. I'll illustrate with an example.

1) You have a group of people
2) You classify them as tall or short, with blue eyes or brown eyes

3) A χ^2 statistic lets you say if blue eyes are associated with being tall or short in anything other than a random way
4) Since everyone knows that having blue or brown eyes has nothing to do with whether you're tall or short, if you do a χ^2 statistic on, say, 20 people, categorized for both of these qualities (eye color and height), it would come out to be non-significant
5) End of illustration. Now, that wasn't so hard, was it?

Notice, when you read my full report you encounter what are called p (probability) values in parentheses, together with χ^2 values. Again, don't panic. The p is the probability that the relationship between the two variables (eye color and height) is random. In other words, that being tall does not increase your probability of having blue eyes, or that height and eye color are totally unrelated.

P goes between 0 (zero) and 1 (one). Very low p values mean *there's a significant correlation between the two variables*. "Very low" would be less than 0.05. Less than 0.01 means there's an even stronger likelihood the two variables (eye color and height) occur together more than by chance.

Okay, you can breathe again; we're done with the math. This is precisely how I identify "risk factors" in my study. (Risk factor is something in your medical history or makeup that makes you susceptible, in this case, to Wind Turbine Syndrome when exposed to turbines.) I applied a χ^2 analysis. For instance, I look at whether a person has or does not have tinnitus when exposed to turbines. I compare that to whether they do or don't have a history of industrial noise exposure. I discovered, in this particular example, that a significant relationship does exist.

We'll come back to this in the Results section, below.

Results

My study demonstrated the following to be the core symptoms of Wind Turbine Syndrome.

1) First, *almost everyone had disturbed sleep.* Two particularly interesting patterns emerged in the disturbed sleep.

a. The first being what we might call "fear" patterns. This would be childhood night terrors and adults waking up alarmed and hyper-alert (i.e., felt they had to check and see if someone had broken into the home, even though they knew they had been awakened by turbine noise). At times adults woke up with a racing heart at night.
b. The second was a tendency to urinate a lot at night. For adults this meant getting up frequently, and for one child it involved bed wetting (which resolved whenever she was away from the turbines).

I didn't look for risk factors for sleep disturbance since virtually everyone interviewed had disturbed sleep.

2) *Headaches.* Slightly more than half the study group had headaches that were worse than what they normally experienced before and after turbine exposure. Headaches that lasted longer and were more severe, in other words.

Half of the people getting headaches were people with pre-existing migraine disorder (i.e., a hereditary tendency to get severe headaches, along with dizziness, nausea, visual changes, or strong avoidance of light and sound during these headache episodes). All the children who got headaches during turbine exposure either had migraine disorder themselves or their parents had migraine disorder.

About half the adults who got headaches during exposure had no risk factors for headache which I could identify. This means that anyone can get severe headaches when exposed to turbines.

3) *Ear symptoms.* Tinnitus was a dominant symptom during exposure. Tinnitus: ringing, buzzing, a waterfall noise, or even a buzzing that seems to be inside the head. Risk factors for tinnitus during exposure were:

a. having some tinnitus before exposure
b. having some hearing loss before exposure
c. a previous industrial noise exposure

All these suggest previous damage to the inner ear, which could come from noise exposure, chemotherapy, certain antibiotics, head injury, or even whiplash injury.

People also experienced pain and popping and a feeling of pressure in their ears.

4) The fourth core symptom I am calling VVVD. *Visceral Vibratory Vestibular Disturbance.* This is a new symptom to medicine, I believe. Before reading further, you should study the VVVD symptom accounts in the Results section (page xxx), so you have a mental picture of what people say they're experiencing.

Once you've looked over those accounts we can move on to consider how the symptoms of VVVD can occur together. The symptoms being:

a. A feeling of internal pulsation, quivering or vibration. For some, breathing feels controlled or restricted.
b. Nervousness or jitteriness. Fear. The urge to flee. The urge to check the house for safety.
c. Shaking
d. Rapid heartbeat
e. Nausea

VVVD is essentially the *symptoms of a panic attack associated with feelings of movement inside the chest in people who have never had panic attacks before* (none of my subjects had).

Because VVVD is so similar to panic attacks, I looked for a correlation between VVVD and a history of any other kind of anxiety or depression or mental health disorder. I found there is no relationship. However *there was a highly significant correlation between VVVD and pre-existing motion sensitivity* (i.e., people who get car-sick, seasick, or had a history of repeated episodes of vertigo).

Out of the 21 adults (age 22 and up) in the study, 14 had VVVD. The two toddlers in the study looked like they had something similar. Though we don't know exactly what they felt, they woke up screaming several times per night, and were inconsolable and hard to get back to bed or to sleep. The two 5-year-olds in the study also awoke fearful in the night.

5) *Concentration and memory.* Almost everyone in the study had some kind of problem with concentration and memory. The more severe concentration problems were linked with a general loss of energy and motivation. What's noteworthy, among many of my subjects, was the degree to which they lost basic skills they had prior to turbine exposure, and the way teachers noticed new problems with kids' schoolwork and sent notes home. (Here, you should read the Concentration and Memory symptom accounts in the Results section, on page xxx, and the accounts of recovery from these symptoms on page xxx.)

For some people, these problems with thinking resolved as soon as they got away from the turbines, or even if the turbines turned in another direction. For others, they did not resolve immediately, but improved gradually over time. To me this suggests that the memory and concentration difficulties were not solely due to sleep disturbance.

I see the cognitive problems as the most worrisome of the whole constellation of Wind Turbine Syndrome symptoms. Somehow the brain seems to be conditioned into new patterns, as though thinking patterns have changed with the distorted vestibular input or prolonged disturbance of sleep. More about this later.

6) The remaining core symptoms were *irritability and anger*, which occurred in most of my subjects, including the children. Often it was the children's behavior and school problems, their irritability and loss of social coping skills, that drove families to move out of their homes and away from the turbines.

7) Most subjects had *fatigue* – sometimes a distinctly leaden feeling – *and loss of enjoyment and motivation for usual activities.* For most this cleared up soon after they got away from the turbines.

8) Finally, I listed clusters of symptoms that subjects told me about, but would require other modes of study (including physical exams or lab tests or x-rays, and a case-control format) to find out if they are connected to turbines. These symptoms occurred in low numbers in my study. They included *lower respiratory infections* (bronchitis, pneumonia, pleurisy) that were unusual for the people who got them, *worsened asthma, unusual middle ear fluid or infections,* and *ocular stroke.*

Though my study cannot prove a connection, I think they are worth attention in a large-scale study of wind turbine health effects.

Discussion

This section is about how I think Wind Turbine Syndrome works, and the ideas I got from the medical literature and my referees. This is the most interesting section of the report—where we join the dots.

I recognized the symptoms of Wind Turbine Syndrome as being something coherent, something that hangs together, because I already knew about what's called *migrainous vertigo* or *migraine-anxiety associated dizziness.*

Migraine is not just a bad headache. It has many other peculiar symptoms associated with it. My husband has had migraines since he was a teen, but he never gets headaches. He gets dizziness, tiredness, and patches where he can't see (scotoma). He has to lie down till it goes away. Some years ago he had a terrible episode of nauseating vertigo (a spinning kind of dizziness), tinnitus, and anxiety that developed into depression. The person who figured out what was wrong with him was the otolaryngologist to whom this book is dedicated, Dr. Dudley Weider.

Dr. Weider taught me how migraine, vertigo, tinnitus, and anxiety are neurologically related—and he treated my husband successfully. I might add that my husband has always been motion sensitive. And I learned that this commonly goes along with migraine.

When I started hearing about the symptoms in Wind Turbine Syndrome, I recognized it as a related complex of symptoms. I had hoped to share this report with Dr. Weider, but, alas, he had passed away. Instead I had the pleasure of sharing it with a group of his former colleagues in otolaryngology. Read through the list of referees and readers of this report, and you will discover it's a Dudley Weider reunion. They taught me many other important matters regarding balance and the inner ear, which I've incorporated into this report.

First, Drs. Lehrer and Black recognized the symptom complex of Wind Turbine Syndrome as similar to the symptom complex of an inner ear problem called endolymphatic hydrops (EH). In the case of EH the

symptoms are continuous or vary for unknown reasons. In Wind Turbine Syndrome these symptoms come and go depending on whether people are near or far from the turbines. Or whether the turbines are making a particular kind of noise, or facing in certain directions.

EH, which includes Meniere's Disease (pronounced "Man-ears") and perilymphatic fistula (where the fluid is leaking from the inner ear into the middle ear), involves distorted pressure relationships between the two fluid compartments in the inner ear: the endolymph and perilymph. This causes erratic and distorted balance and (often) hearing signals to be sent to the brain.

This brings us to the balance system and how it works. It's a complex system that penetrates many areas of the brain and draws sensory signals from all over the body. Other senses have only one kind of sensory input, whereas the balance system has four.

By balance system I mean a) *how the body maintains its upright posture* and also b) *everything to do with motion and position awareness*. For example, the balance system is highly active during the turns and twists of diving or gymnastics, even though a person is not staying upright.

Why all this focus on the balance system? Because I think that *people susceptible to imbalance are especially susceptible to Wind Turbine Syndrome*. So I need to explain the different ways people become imbalanced, and how the air pressure variations, or sound, from wind turbines may be triggering an abnormal sense of motion in susceptible people.

As I mentioned before, *motion* and *position* signals come from four discrete body systems and are integrated by balance centers in the brain:

1) eyes (the visual center)
2) dedicated motion and position sensing organs in the inner ear (the vestibular center)
3) stretch receptors from muscles and joints all over the body, and touch receptors in the skin (the somato-sensory center)
4) stretch and pressure receptors associated with organs in the chest and abdomen

The balance system requires that at least two of the first three channels, that we will call visual, vestibular, and somato-sensory, be working every moment if we are to maintain balance. Hang onto this point; it's extremely important. We might call it the *Law of Balance.*

For example, the vestibular organs in the inner ear tend not to work so well in older folks. If the inner ear is not sending correct signals, people are more dependent on what they can see and on what their feet and legs are feeling, to keep their balance.

Since two channels have to be sending signals for balance to work, these people are in trouble in the dark.

If you have good balance, try this experiment: stand on one foot and feel all the little corrective movements your foot and ankle are making to keep you upright. People with normal balance can stand on one foot indefinitely.

Now, close your eyes. See how long before you have to put your other foot down to keep from falling over.

You can't keep your balance in this situation because you've deprived yourself of both vision and adequate somato-sensory input from the legs—and one system, the vestibular input from the inner ear, is not enough. (If you don't have good balance, keep both feet on the floor when you close your eyes, and you still may notice a difference.)

Variations in balance function seem to fall into four broad categories.

1) *The first is very young age.* Little children fall down a lot. As kids get older and improve their balance, they can do more complex things without falling. At very young ages, children are mapping their entire sensory system onto the world. For example, an infant figures out how far he has to reach his arm to touch something, and what that looks and feels like. This gives him a sense of distance, mapping that concept of distance onto his visual sensors and the coordinated stretch receptors of his arm and shoulder.

   This process of learning where the parts of the body are in space, through increasingly complex activities, continues through childhood. In its early stages, children are more susceptible to balance disturbance.

2) *A second origin of balance variation is differences in the central (brain) processing of balance and motion-related signals.* People who are motion sensitive, which includes many people with

migraine disorder as well as other people, have difficulty successfully integrating the signals from the different sensory channels of balance. Their brains tend to over-emphasize or under-emphasize certain channels.

For example, in a person with migrainous vertigo and tinnitus—like my husband—the signals from the inner ear may be turned up too loud. So, centrally, the brain has to turn these down. It has to deal with the over-intensity of one signal. Or it may not be that they're too loud, but distorted, in which case there's an even greater need for the brain to down-weight the signals from that channel.

When we turn down the signals from the inner ear, we become more dependent on the visual channel or the somato-sensory channel. People who are visually dependent for balance often have trouble with heights, like being high up in a building or on a cliff. (Witness my husband.) This is because, when everything is far away, there's less visual position information that can be drawn from what one sees (less retinal slip and parallax changes as one moves, for example).

Someone who is surface dependent, on the other hand, may be in more trouble when the surface is slippery, because he is relies more on the position information coming from his muscles and joints. These signals are distorted by the slippery surface.

3) *The third source of balance variation or dysfunction is inner ear damage, or congenital or developmental malformations of the inner ear.* Damage may come from loud noise or blast exposures, head or neck injury (including minor ones like whiplash or a concussion), complications of repeated or chronic middle ear infections in childhood, or exposure to certain chemicals (aminoglycoside antibiotics or certain kinds of chemotherapy). There is also endolymphatic hydrops, an inner ear pathology (described above) that includes Meniere's disease and perilymphatic fistula. Autoimmune disorders like lupus can also cause endolymphatic hydrops.

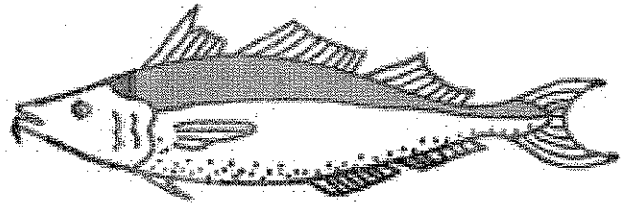
4) *The fourth source of balance variation or dysfunction is older age.* There seems to be deterioration of inner ear function after about age 50, varying among people, of course.

This brings us to *compensated vs. uncompensated balance dysfunction.* If you happen to have a balance dysfunction and yet are able to compensate for it, you feel fine: you keep your balance. On the other

hand, if there's an additional challenge, or distortion from another channel, then you're off balance—you feel unsteady or dizzy, or have vertigo or motion sickness. This is *uncompensated balance dysfunction.* Because of what's called "the system's redundancy" (the "system" in this case being the brain) brain balance centers can ignore or down-weight anomalous (false) signals from one channel, *but they can't for two channels*.

People who suffer from Wind Turbine Syndrome have, I believe, a compensated balance problem at baseline, in one of the four ways described above. By *baseline* I mean: they had a compensated balance problem before they were exposed to wind turbines. *Exposure to wind turbines pushes them over the edge, since, as I said above, the brain can't ignore disorienting signals from two channels*. (Remember, one set of false signals is now coming from the turbines. The other set of disorienting signals is coming from any of the four categories described immediately above.)

How, you ask, might sound pulsations (coming from wind turbines) be disrupting human balance signals?



Good question. Let's start with fish. The otolith organs of the vestibular system are highly conserved through evolution. Meaning, they're similar in fish and all other vertebrates—amphibians, reptiles, mammals, and birds—that evolved from fish. In fish these organs detect upright position (a fish's version of balance), and also low frequency noise and pressure variations in the water.

This detection of pressure variations and noise, including low frequency noise, is important for detecting the movements of other animals to escape being eaten, catch prey, and navigate through the oceans using the low frequency sound from distant waves breaking on shores. ("No, Virginia, they don't use Google maps or GPS locators.")

Thus the otoliths have a long evolutionary history of being sensitive both to gravity and noise/pressure variations. It makes sense that a system with a critical role in escaping predation would be hardwired into the brain's networks for fear and alerting, for fast escapes. Think too about all those stories about animals

detecting and fleeing earthquakes, tsunamis, incipient volcanoes, and ice breakup—things that rumble or make low frequency noise and vibration—long before human beings become aware of them.

Detection of this kind of signal is tied to fear responses: the animals flee. Animals apparently pick up this kind of signal through the ground, but there is also evidence that animals, including us, are sensitive to air pressure changes which are not sound. Weather changes influence mood and energy in many people, with higher barometric pressure associated with better mood and more energy. Birds sense big snowstorms coming, and feed like crazy before the storm rolls in.

What about that fourth balance channel, the stretch and pressure receptors in the internal organs? This fourth one, called *visceral graviceptors* and discovered relatively recently (in the 1990s, by a German researcher), is especially fascinating. (This is the balance channel many physicians are unaware of, since we were all taught in medical school that only three senses feed into balance.)

Visceral graviceptors are based on stretch and pressure receptors in and around internal organs. These receptors can let you know you're upside-down because there's more blood in the chest, making the blood vessels weigh more. Or they let you know by increasing the pressure of blood inside organs or blood vessels. This is thought to be a reason why astronauts hurling through outer space can have the sensation they're upside down, because gravity is no longer pulling so much blood into the legs and more of it is in the organs and vessels of the chest.

There are suggestions in the balance literature that visceral graviceptors play an important role in car-sickness and seasickness, by being the detectors for unusual up-and-down motions at odds with what the rest of the balance system is saying. It helps in seasickness, for instance, to stand up and look out at the horizon. This brings information from the eyes and stretch receptors in legs in line with the vestibular and visceral motion signals.

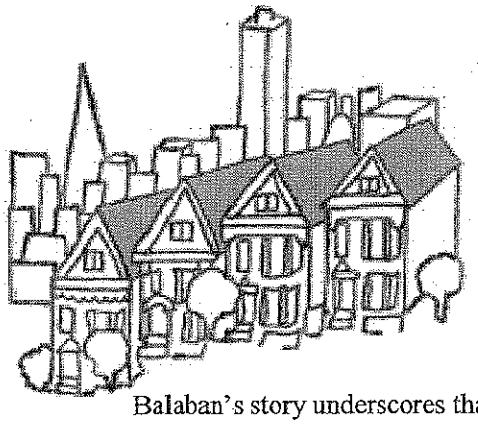
The point being that anomalous (unusual) signals, including from the newly discovered visceral graviceptors, disturb the balance system.

The VVVD story also involves understanding how the chest is a receptor for air pressure fluctuations. (Every form of sound in air, from low frequency to high frequency, consists of strings of air pressure pulses.) Briefly, when we breathe, our airways and lungs, which fill most of the chest, are open to the air.

Sound pressure waves can easily enter, and can set this elastic and mobile system moving with very little energy. (For a description of chest wall and diaphragm dynamics, see the explanation on page xxx.)

The internal graviceptors provide a potential link between the chest pressure fluctuations and the set of sensations and symptoms I call VVVD—the same set of neurologic symptoms seen in chronic inner ear disorders. The internal graviceptors may well provide the neural connection between chest pressure and weird discordances picked up by the balance system, producing similar sets of symptoms in these two situations. Or, as suggested by Dr. Owen Black (a balance and inner ear researcher), there may also be a relationship between pressure in the chest, the fluid around the brain, and the fluid in the inner ears in some people with particular inner ear problems.

Now consider how the balance system in the brain is neurologically tied in with fear and anxiety. Here we look to the work of Dr. Carey Balaban, a brain researcher. Balaban studies the neural networks linking balance with the brain centers controlling anxiety and fear, and with the autonomic responses and aversive learning that are also part of VVVD and Wind Turbine Syndrome. (The *autonomic nervous system* controls all the bodily functions that you don't have to think about and, in fact, you can't control. Such as blood pressure, heart rate, sweating, and digestion.) Disordered balance signals feed directly into fear and anxiety. *It's not because you start out scared or negative; it's because of a physiologic reaction to being off balance.* This is Balaban's point. He shows the actual nerve networks mediating these communications in the brain.



Balaban illustrates with a story. Imagine you're stopped in your car on a hill. Say, San Francisco. Out of the corner of your eye you see the truck next to you starting to inch forward. This immediately gives you impression you're starting to slip backwards! You panic! You jam your foot on the brake! The fear subsides as you realize you are in fact … not moving.

Balaban's story underscores that when you sense you're not stable in space—you're going to fall, you're moving when you don't expect it—it grabs all your attention, immediately, with alerting and fear. He also points out that when the sense of moving unexpectedly goes on over a long time, as in vertigo, so does the sense of fear.

Studies by psychiatrists and balance specialists show how the linkages between anxiety and balance problems play out clinically and in real life. A mild form of balance disorder is called *space and motion discomfort*, where people feel uncomfortable or dizzy in situations like looking up at tall buildings, closing their eyes in the shower, leaning far back in a chair, driving through tunnels, riding in an elevator, or reading in the car. These people also have abnormalities on balance testing. It's usually a central balance problem, meaning the brain has difficulty integrating all the different signals coming into the balance system, and deciding which ones to ignore if they don't match.

Space and motion discomfort is common in people with migraine disorders. So are dizziness, vertigo (spinning dizziness), and motion sickness. Balance testing is abnormal in people with migraine disorders compared to people who get other kinds of headaches, especially if the migraine patients tend to get dizziness or vertigo. The balance problems in migraine disorder, incidentally, can be inner ear or central (brain-based).

Anxiety problems are also associated with migraine, sharing a common thread in the serotonin systems of the brain. Space and motion discomfort is common in people with anxiety disorders. Balance testing shows that anxiety patients have higher vestibular (inner ear) sensitivity than people without anxiety problems. When balance testing is done in people diagnosed with panic attacks or agoraphobia (fear of leaving the house), a high number are found to have abnormalities of vestibular (inner ear) function—more than 80% in some studies. This is especially true if the people have episodes of dizziness between panic attacks.

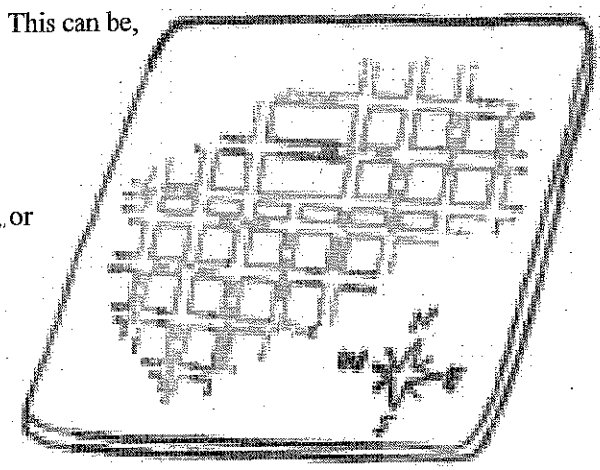
In sum, *there is a robust clinical literature supporting the biological connection between balance problems and anxiety, and between balance problems and panic attacks, in particular.* It makes eminent clinical sense that *disturbing a person's balance system can lead to fear, alerting, and panic, including physical symptoms like fast heartbeat and shakiness.*

I've talked about how the visceral graviceptors in the chest might be stimulated and lead to balance disturbance, but not so much about the other channels of balance. In my study, two subjects, both adult women already prone to vertigo, were very sensitive to the visual channel. Both developed severe headaches when exposed to the moving shadows of turbine blades.

Some subjects were able to feel vibrations from the ground in their lower legs, opening the possibility that the somatosensory channel (stretch scepters from the muscles and joints, and touch receptors from the skin) could be disturbed.

Many of my subjects had ear symptoms, including tinnitus, ear pressure, ear pain, or a physical feeling of noise inside the head. If the air pressure fluctuations from the turbines can produce these symptoms, which are all different from hearing the noise, might they also perturb the balance organs of the inner ear? The labyrinthine (inner ear) organs are delicate, interconnected membranous sacs with fluid inside and outside, sensitive to minute shifts in pressure and position. Audible sounds stimulate the cochlea, but certain sounds can also stimulate the saccule in humans (the otolith organ that tells us if we are upright). The otolith organs of certain fish, which are similar to ours, are known to detect low-frequency sound, aiding in navigation. This gives us reason to think, for both animals and humans, that certain types of noise may be able to stimulate the balance parts of the inner ear, especially the saccule, causing disturbance to motion and position sense.

The plot thickens. Thinking and memory: current research demonstrates that these, too, depend on coherent vestibular signaling. If you don't know which way is up, literally, at all times, your brain can't figure out a multitude of things related to position in space. This can be,



a) *position in real space*, like
    a. remembering how to get somewhere or
    b. figuring out how to put something together, or
b) *position in conceptual space*, like
    a. the distance between two numbers or
    b. the position of events in time or
    c. the categorization of objects in memory

Research is supporting what doctors who treat balance problems have seen for years: *struggles with short-term memory, concentration, multi-tasking, arithmetic, and reading are common in patients with balance disorders.*

Neuroscientists have recently shown that nerves from the vestibular system follow a direct path to the hippocampus, a brain structure critical for memory in general and spatial learning in particular. People with no inner ear input to the brain at all (the nerves having been cut years before to remove tumors)

cannot do experimental tasks involving navigation, and their hippocampi (plural of hippocampus) are smaller than normal. (Conversely, taxicab drivers in London have extra-large hippocampi, the size depending on how many years they have been driving and storing in their brains their personal map data of locations, shortcuts, and one-way streets.)

Functional MRI and PET scans (PET scans don't scan your pet, just as CAT scans don't scan your kitty; see Glossary) now allow researchers to see which parts of the brain are used for different tasks by awake humans while they are doing things. Stimulating the vestibular (inner ear balance) system lights up many areas in the brain, including those used for mental representations of space and mathematical thinking.

If the vestibular input is distorted (for example, by putting ice water in one ear), people make more mistakes in purely mental spatial tasks, like imagining a certain object in detail or imagining rotating it. These people were sitting still at the time, eyes closed, just thinking, not trying to keep their balance or having to judge where they were in space at all. Nonetheless, when signals came from one inner ear indicating movement—signals out of whack with all the other signals their balance centers were receiving—they remembered the objects less accurately and made mistakes when imagining them in different positions.

Disordered signaling from the inner ear at the time of spatial thinking, in other words, degrades both memory and concentration.

A cluster of brain centers that receive signals from the inner ear (meaning, they become active on functional MRI or PET studies when the vestibular organs are stimulated) is in the right parietal ("pair-eye-ital") lobe of the brain, towards the upper middle on the right side. There can be some very weird outcomes if these centers are lost to a right parietal stroke. Called "hemineglect" (hemi-neglect: meaning neglect of half the body and half of space), these poor people can have so much unawareness of the left side of space that they can be unaware that their left arm is paralyzed or the left side of their body undressed. Vestibular stimulation, however, temporarily reverses the neglect, so that these people become aware of the left side again in a more normal way.

People with hemineglect have typical types of errors on visual search and visual memory tasks, with answers biased away from the left and towards the right sides of images. Left vestibular stimulation corrects or improves performance on these tasks.

Other studies of people with hemineglect let us see what other kinds of mental tasks are "spatialized," meaning, they require the spatial types of thinking done in these right parietal lobe centers linked to the vestibular system. Spatialized thinking includes mathematical operations like forming a mental image of a ruler (lower numbers on the left, higher on the right), and imagining the midpoint between two numbers. It also includes clock representations of time, and spelling at the beginning (left) and ending (right) of words. Studies of powerful thinkers also show how important spatial thinking is: great mathematicians think of math in spatial terms (which is efficient, because the actual neural representation of numbers is spatial), and outstanding memorizers use spatially oriented strategies.

The punchline being, when there's a lack of input from the vestibular system, spatial thinking gets shut down. Whereas when the input from the vestibular system is confused (disordered), spatial thinking gets mixed up. Spatial thinking absolutely requires vestibular stimulation. Disordered vestibular information knocks it off balance, so to speak, rendering it less efficient and inaccurate.

Spatial thinking, it must be emphasized, is much of what we do with our brains.

Now, think about the specific tasks my study subjects had trouble with—what they spontaneously told me about themselves and their children, along the lines of,

a) "I can't believe I can't manage something this simple anymore!"
b) "He (my child) knew how to do this, and now he can't do it at all and gets really mad and frustrated when I make him keep trying!"

The letter and number refers the person's Family Tables. I put a description of the *spatial quality* of each task in italics:

A1 Remembering what he had come to get when he arrived at a store. *Spatial memory for the image of what he was searching for.*

B2 Remembering a series of errands and things to get in town. *Spatial memory for the objects and places to get them, spatial calculation of the most efficient path and order.*

C1, D1, G3 Reading. *Conversion of spatial input (words on page) to language and then to concepts and imagery (which are also spatial). There is also direct vestibular control of eye movements.*

C2, G2 Multitasking in kitchen and household. *Having an internal map of the locations and timing of multiple things at once, inserting tasks and events into the map and not losing awareness of them when out of sight.*

C7 Math—lost skills and forgot math facts. *Spatial representation of numbers and number relationships.*

E2 Spelling, writing. *Putting letters in the right order so the word looks right; changing language into a visual representation.*

F2 Assembling furniture. *Being able to convert written instructions or diagrams to 3-dimensional mental representations of what she was supposed to do with the pieces.*

F2 Following the steps in a simple recipe. *Picturing and ordering the steps in mind from the written instructions.*

F2 Following the plot of a TV mystery. *Noticing, remembering, and putting together visual clues.*

F3 Did worse than in past on national exams. *Outstanding memorizers use spatial strategies, as described above.*

H3 Reading, spelling, math. *All these have significant spatial components.*

I1 Professional landscaping and gardening—loss of concentration. *Planning and arranging things in space, remembering where you put down a tool, judging if something you're building is*

turning out right and how to fix it, planning steps of tasks efficiently in time and space, not forgetting steps.

J1 Paying bills. *Mathematics, memory for objects and services purchased, mental calculation of future needs.*

These are not all the tasks people said they were having trouble with, but they are the majority. Making sense? *Balance signals messed up, spatial thinking full of errors and inefficiencies, and people are enormously frustrated over normal, common sense things they suddenly can't do efficiently.* ("Common sense" has a big spatial thinking component, too.) Early school learning is thrown off, as well as reading and certain higher memory and problem-solving tasks in adults.

Interference of noise with reading and children's learning is not a new discovery; there is an extensive literature on it. In brief, environmental noise, like airport or traffic noise, makes children learn to read more slowly. In these studies, large numbers of children were studied in carefully controlled exposed and non-exposed groups, by choosing school districts at different locations relative to airports. Children were exposed to the extra noise both in school and at home.

In one study, a city closed an old airport and built a new one, and researchers had the opportunity to follow the reading skills of both sets of children over time. The ones living near the airport that closed showed improvements in their reading. The ones near the new airport showed slower learning after planes started flying in and out.

One study looked at children living in an apartment building next to a busy highway. Those on the higher floors, where it was quieter, had better reading scores and better ability to tell word sounds apart.

The effects of noise on reading ability go beyond the distracting effects of noise, and are linked to problems with language processing—like differentiating between sounds in noisy environments.

Noise can affect thinking in adults, too, at loudness levels nowhere near the levels that harm hearing. In one study, industrial workers worked on psychological tests while exposed to 50 dBA broadband noise (like white noise or machine noise) with or without low frequency components. The noise with low frequency components interfered with test performance more than the noise without the low frequencies, especially in individuals who rated themselves as sensitive to low frequency noise. Neither type of noise

was considered more annoying than the other, nor did subjects become accustomed or sensitized to the noise.

Many environmental noise studies look at effects on sleep, stress hormone (adrenalin, cortisol) output, blood pressure, and cardiovascular risk factors in general. Noise at night can significantly disturb sleep even when the person does not remember waking up. Since the sorting and storage of daily memories occurs during sleep, especially dreaming or what's called REM sleep (rapid eye movement), sleep disturbance by noise, even without known awakening, interferes with memory and learning.

In children, nighttime low frequency (rumbling/vibrating) noise from trucks has been shown to produce more stress hormone at a time of night when it's not usually produced (i.e., the wrong time of night), than gets produced in the same children exposed to regular nighttime car traffic noise. *In other words, low frequency nose stimulates elevated stress hormone production in children during nighttime sleep.* (Elevated cortisol levels are also known to harm memory and learning, reducing the survival of new hippocampal memory cells, as in chronically abused children.) High adrenalin or cortisol levels elevate blood sugar and increase blood pressure, increasing cardiovascular risk.

Interestingly, the levels of noise that disturb sleep are quite low. Noise events of 32 dBA cause people to move in sleep, showing a low level of arousal. Noise events of 35 dBA cause arousals that can be seen on a brain wave study (EEG). Conscious awakenings occur at 42 dBA. This is why the World Health Organization (WHO) recommends 30 dBA as an acceptable indoor nighttime noise level.

I don't present noise analyses in this paper—something that clearly needs to be done, but requires resources I didn't have—but I find that published descriptions of people's experiences in documented low frequency noise are very similar to what my study subjects noticed and described to me. If you haven't already done so, I recommend you read the section of clinical text called "Low-frequency noise" (pages xxx-xxx).

First, I quote Dr. Birgitta Berglund (the dean of community noise studies and lead editor of the 1999 World Health Organization *Guidelines for Community Noise*) on the reasons she thinks many of the adverse effects of noise in general are due to its low frequency components. She calls attention to how low frequency noise travels farther than other noise without losing its power, travels through walls and hearing protectors, rattles objects, sets up vibrations and resonances in the human body, and is linked to motion sickness even when vibration is not present. The lower frequencies can make it hard to

distinguish sounds at higher frequencies, like speech. Noise with low frequency components is experienced as louder and more annoying than noise at the same dBA level without low frequency components. All this is discussed in the "Low frequency noise" section in the clinical text. Again, it's well worth reading.

It's important to remember that the term "annoyance" in community noise surveys is used as a shorthand for a variety of negative reactions. Some of them severe. "Apart from 'annoyance,'" states the WHO, "people… exposed to community noise… report anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation, or exhaustion."

In the clinical report, I quote as well several other small studies of situations wherein people were exposed to documented low frequency noise. For instance, the symptoms that healthy young men felt when exposed to high amplitude low frequency noise, for only 2-3 minutes, in a NASA test facility in the 1960s, included fatigue, reduced efficiency at performing tasks, tickling in the ear, chest vibrations, and a feeling of fullness in the throat—all symptoms I heard about from my study's participants.

Indeed a case report from Germany in 1996 may well be Wind Turbine Syndrome, since the source of the low frequency noise (actually infrasound, below 10 Hz) was never identified. It's an especially interesting story. The couple's symptoms and the intensity of noise below 10 Hz both varied with the wind and weather, and were worse in winter. Their symptoms were,

a) sleep disturbance
b) headache
c) ear pressure
d) not feeling well in a general way
e) decreased ability/efficiency in doing things
f) chest symptoms described as shortness of breath and a tingling/crawling sensation

Symptoms occurred when the sound pressure level at 1 Hz was 65 dB, well below the couple's own hearing thresholds measured in a sound lab. All the frequencies responsible for the symptoms, which were all below 10 Hz, had sound pressure levels below 80 dB.

We now know that sound levels near turbines easily fall within these ranges, as measured by a Dutch physicist several years ago.

The 1996 German case, above, and another series of cases, also by German noise control officials, both *emphasize how the symptoms and the degree to which the people were bothered increased over time after they moved into the home or apartment with low-frequency noise. They did not get used to the noise. In fact, the opposite: they became sensitized to it over time.* At first it wasn't so bad, but it grew worse and worse.

My study subjects said the same thing, as they compared turbine noise to other types of noise, like traffic, that they easily got used to. Many said that wind turbine noise would not sound loud to people who did not live with it, but several also mentioned visitors being bothered if they spent the night. When they moved away from their turbine-exposed homes, all the families moved into towns and villages with more traffic noise, but no risk of turbines being build next door.

Hence, glib claims that "you will get used to wind turbine noise," are contradicted both by people who struggle to live with it, and by clinical evidence.

Both German case studies focused on the ability of low frequency noise, with its long wavelengths, to pass through walls and then reverberate or set up resonances inside rooms. The authors of the case series measured the difference in low frequency noise intensity near walls and away from walls, picking up nodes of higher intensity away from walls, like a standing wave in a stream.

In my study, Mr. and Mrs. G (G1 and G2) both identified a spot in one room where they got symptoms, a feeling of internal vibration for Mrs. G and the beginnings of nausea for her husband. They could not feel any vibrations with their hands if they touched walls or furniture. I think this was one of those places where the low frequency sound (air pressure) waves overlapped in such a way, as they bounced around the room, that they made a stable spot or standing wave of increased intensity.

Swedish researchers verified in a survey study of hundreds of households that the amount of noise needed for a wind turbine to cause severe annoyance was much lower than the amount of noise road traffic, airplanes, or trains would have to make to be severely annoying to as many people. "Amount of noise" was measured in dBA, which filters out the effect of any low-frequency components, and averaged over time. Fifteen percent of people were highly annoyed at 38 dBA of wind turbine noise, compared to 57 dBA for aircraft, 63 dBA for road traffic, and 70 dBA for trains. By the time the wind turbine noise level

reached 41 dBA, 35% of people were highly annoyed. Sixteen percent reported sleep disturbance over 35 dBA of outdoor turbine noise.

When these researchers interviewed some of the people surveyed, they found the same sorts of problems I encountered in my study, including people who had moved out of their homes because of the noise or rebuilt their homes to try to exclude the noise. Some reported feeling invaded or violated by turbine noise, being sensitive to blade motion as well as noise, and the loss of their ability to rest and feel restored at home.

From this one can reasonably conclude that, for wind turbines, perhaps unlike other sources of noise, *community standards allowing 45-55 dBA outside neighboring homes are asking for trouble.*

George Kamperman and Rick James, two independent American noise control engineers with decades of experience working with industrial noise and communities, recommend a noise standard based on quietest background ambient noise and using C-weighted as well as A-weighted measurements, so that the low frequency components are also controlled. Their specific recommendations—for how the noise measurements should be done and how the procedures should be spelled out in a local ordinance—were presented at the annual conference of the Institute of Noise Control Engineering/USA in 2008 and are posted on the Wind Turbine Syndrome website at http://www.windturbinesyndrome.com/?p=925. An important part of Kamperman and James's method is that as turbines get larger, setbacks will have to be longer.

But the simple answer is: keep wind turbines at least 2 km (1¼ miles) away on the flat, and 3.2 km (2 miles) in mountains. These are minimum distances; Kamperman and James's methods will in all likelihood recommend longer setbacks, especially in rural areas that are very quiet at baseline. Secondly, all wind turbine ordinances should hold developers responsible for a full price (pre-turbine) buy-out of any family whose lives are ruined by turbines—to prod developers to follow realistic health-based rules and prevent the extreme economic loss of home abandonment.

Table 1B: Cases: physical attributes

Case	Distance to closest turbine	# turbines	MW per turbine	Year placed in operation	Hub height	Total height	Terrain	Configuration of turbines	House construction
A	1000 m (3281 ft)	10	3	2007	90 m	135 m	Hilly with rocky ridges	10 in line point at house at hub level	Wood frame
B*	1000 m (3281 ft)	10	3	2007	90 m	135 m	Hilly with rocky ridges	10 in line point at house at hub level	Wood frame
C	305 m (1000 ft)	17	1.8	2004-05	80 m	125 m	Rocky peninsula	On three sides	Wood frame
D	548 m (1798 ft)	22	1.8	2006	78 m	117 m	Flat farmland	Group on one side	Wood frame
E	423 m (1388 ft)	45	1.5	2006	87 m	120 m	Flat farmland, swamp	On three sides	Wood frame with stone front
F	930 m (3051 ft)	8	2	2006	59 m	100 m	Flat farmland	5 in line point at house	Brick on cement slab
G	596 m (1955 ft)	32	3	2006	80 m	125 m	Rocky hills	Above house on three sides	Stone cottage, walls 2 ft. thick
H	1500 m (4921 ft)	11	2.3	2005	80 m	121 m	Rocky hills	Above house on three sides	Stone cottage, cement slab
I	350 m (1148 ft)	10	2	2006	78 m	121 m	Rocky hills	Across valley at higher elevation	Wood frame
J	732 m (2400 ft)	40	2	2007	80 m	123 m	Ridges and valleys	6 in L above house on two sides	Wood frame

*Families A and B are related and own separate homes on the same property

Table 1C: Cases: demographics

Age	Male	Female	Total
<1	1	1	2
1-3	1	1	2
4-6	2	1	3
7-11	3	0	3
12-15	1	2	3
16-21	2	2	4
22-29	0	0	0
30-39	2	2	4
40-49	3	2	5
50-59	4	5	9
60-69	1	1	2
70-79	1	0	1
Totals	21	17	38

Family Table A1 (page 1 of 2)

130

Person
Mr. A
Age
32
Pre-exposure health status
Good
Health history
No significant
Previous noise exposure
Diesel fishing boat from childhood
Time to onset of symptoms
Immediate with progression

	Pre-exposure	During exposure*	Post-exposure**
Sleep	Good but always easily awakened by noise.	"I didn't really." Hard to fall asleep. Frequent awakening due to child's frequent awakening.	Good, at baseline. Child sleeping through night.
Headache	Rare, mild	Continuous headache at home which resolved after several hours away and resumed several hours after return, with onset 3 wks into turbine start-up process. OTC and prescription analgesics, addition of glasses not helpful.	Resolved
Cognition	Normal. Runs own fishing business. Mild difficulty with memory, especially for names and faces.	Memory problems: "You'd think I was 99." When arriving at a store or storage building, could not remember what he had come to get without a list.	Partial recovery: self-rated memory 80-85% at baseline, 2% during exposure, and 10% at 6 weeks after moving
Mood	Good. Usually does not show annoyance.	Loss of usual energy and enjoyment for spring fishing season. Mildly irritable.	Anger about home abandonment, otherwise resolved.
Balance/equilibrium	Normal, never carsick or seasick	"A little shaky on feet every now and then" at home.	Resolved

Family Table A1 (page 2 of 2)

	Pre-exposure	During exposure*	Post-exposure**
Ear/hearing	Mild subjective hearing loss attributed to diesel engine exposure, no tinnitus.	Repetitive popping in ears for first 3 weeks. Tinnitus started several weeks after headache onset and worsened over time.	Resolved
Eye/vision	Normal without glasses	Burning sensation in eyes. When headache and tinnitus were severe, eyes "felt like they were going to fall out on the table if you looked down." Had normal eye exam.	Resolved
Other neurological	Normal except mild concussion age 14	No change	No change
Cardiovascular	Normal including BP (110-120/80 in 2006)	Mild diastolic hypertension on one reading (128/94 on 4/4/07)	No further BP measurements obtained.
Gastrointestinal	Normal	Nausea when headache was severe. No vomiting or other gastrointestinal changes.	Resolved
Respiratory	Normal except smokes	No change	No change
Other		Symptoms were present in all wind directions, better during rain, and worse with wind from direction of turbines or from the 180 degree opposite direction.	
		"You feel different up there, draggy, worn out before you even start anything." "It was a chore to walk across the yard."	When visiting family 100 km away, "I felt better all over, like you could do a cartwheel." Feels well at new house.

*Exposure period 5 months.

**Interviewed 6 weeks after move.

Family Table A2 (page 1 of 2)

Person
Mrs. A
Age
33
Pre-exposure health status
Good. Pregnant during exposure and delivered at term 4 days before moving.
Health history
Polycystic ovarian syndrome and metabolic syndrome. Caesarian section for first delivery.
Previous noise exposure
Worked at biomedical chemical plant for 5 yrs with 1-2 hrs/wk exposure to noisy areas.
Time to onset of symptoms
Immediate with progression

	Pre-exposure	During exposure*	Post-exposure**
Sleep	Normal. Sleeps through noises other than children.	Frequent awakening	Normal, resolved
Headache	Rare, mild	Occasional headache	At baseline
Cognition	Concentration "great," works as accountant	Noticed concentration problem at work when training someone; working to focus; trainee had to help	Resolved
Mood	Good, including during and after first pregnancy	Irritable	Resolved
Balance/equilibrium	Gets seasick but not carsick	Slight unsteadiness	Resolved
Ear/hearing	Normal hearing. Persistent middle ear fluid in late 20's, resolved. Tinnitus in past when emerging from noisy plant.	Repetitive popping in ears and decreased hearing for first 3 weeks, then tinnitus began. Tinnitus varied with exposure and worsened over time.	Tinnitus resolved, but has new difficulty understanding conversation in a noisy room. Has to watch speaker's face.
Eye/vision	Wears glasses. Eyes water if strained.	No change	No change
Other neurological	Normal, no concussion	No change	No change
Cardiovascular	Normal except h/o temporary stress-related hypertension at age 22.	Normal	Normal
Gastrointestinal	Nausea and GER during pregnancy	No change	Resolved after delivery

Family Table A2 (page 2 of 2)

	Pre-exposure	During exposure*	Post-exposure**
Respiratory	Normal, no asthma or smoking.	Lower respiratory infection for 6 weeks not treated until after delivery and move.	Resolved
Other		"Not noisy like a chainsaw, more like pulsating annoyance. To another person it wouldn't sound loud."	

Animals	Dog barks at windmills and up more at night	Improved dog behavior

*Exposure period 5 months.

**Interviewed 6 weeks after move.

Family Table A3

Person
Son A
Age
2½
Pre-exposure health status
Good
Health history
Term birth, normal growth and development.
Previous noise exposure
No significant
Time to onset of symptoms
Immediate

	Pre-exposure	During exposure*	Post-exposure**
Sleep	Slept through night 12 hrs without awakening. Always a good sleeper.	Night terrors 2-5 times each night, 30 min to calm down and return to quiet sleep.	At baseline. Night terrors resolved. Awakes once briefly for drink and goes back to sleep.
Headache	None	No apparent headaches.	None
Cognition	Good speech development with lots of words and no sound confusion.	Began to confuse *t* with *k* sounds and *w* with *l* sounds.	Vocabulary, sentences, and conversational skills are good but still confusing sounds.
Mood	Good-natured, sensitive, bright, listened well for age.	Oppositional, cranky, "a completely different kid for a few months."	"Instantaneous" resolution when moved, resumed former behavior.
Balance/equilibrium	Normal for age.	No change	No change
Ear/hearing	Normal hearing test at birth. One episode of otitis media.	Pulled ears and got cranky synchronously with adult episodes of headache and tinnitus.	Resolved
Eye/vision	Normal	No change	No change
Other neurological	Normal	No change	No change
Cardiovascular	Normal	No change	No change
Gastrointestinal	Normal without h/o GER	No change	No change
Respiratory	Normal without h/o asthma.	No change	No change

*Exposure period 5 months, age 27-32 months.

**Information provided by parents 6 weeks after move.

Family Table B1 (page 1 of 2)

Person
Mr. B
Age
55
Pre-exposure health status
Good
Health history
Surgery 4 times for benign prostatic hypertrophy, once for hand injury
Previous noise exposure
Diesel fishing boat since childhood
Time to onset of symptoms
Immediate with progression

	Pre-exposure	During exposure*	Post-exposure**
Sleep	Good	Delayed onset and repeated awakenings; prescribed sleep aid.	Resolved
Headache	Rare, mild	Continuous, head and ears "sizzling." "It got in your head and would dang well stay there." Started "at back of head, then down sides, then affected right eye." Prescription and non-prescription analgesics minimally helpful.	At baseline
Cognition	Normal	"Trouble remembering;" "a little problem concentrating" blamed on sleep deprivation	"Pretty good, a little problem still."
Mood	Good	Stress, "lots, pretty near more'n I could take, it just burnt me, the noise and run-around"; prescribed anxiolytic.	Improved, still takes some anxiolytic.
Balance/equilibrium	Normal, never seasick or carsick, no vertigo.	Wobbly, staggering, off-balance "like had drunk." No falls. Occasionally felt dizzy.	Resolved, on roof shingling without problems.
Ear/hearing	Normal hearing on left and mild sensorineural loss at 4kHz on right in 2006. Intermittent left tinnitus since 2005.	Tinnitus continuous and bothersome, "ringing and sizzling," and interfering with conversation comprehension. Ears popped "like an airplane." Ear wax increased.	Resolved
Eye/vision	Normal with reading glasses.	Intermittent right eye pain "like a force on it, like pressure on the eye, the inside part, in the head." No change in vision. Eye pain/pressure synchronous with headache.	Resolved

Family Table B1 (page 2 of 2)

	Pre-exposure	During exposure*	Post-exposure**
Other neurological	Normal, no concussion	No change	No change
Cardiovascular	Normal with BP 126/82, 126/88, 112/70 in 2006	Mild BP elevation 140/80, 132/90, 152/92. After started anxiolytic, BP 128/84.	Resolved, BP 110/68
Gastrointestinal	Normal, no GER, not prone to nausea.	Frequent nausea.	Resolved
Respiratory	Slight asthma as child. Never smoked.	Two episodes of feeling of weight on chest while lying on couch, which resolved when he stood up. Lower respiratory infection in 5th month of exposure.	Normal
Rheumatologic	Osteoarthritis	No change	No change
Other	Little road traffic or other noise	"That stuff [turbine noise] doesn't get out of your head, it gets in there and just sits there - it's horrible."	Not bothered by "all kinds of traffic" at new location; "after a while you don't hear it."
		He felt pulsation in ears and chest when there was fog in the valley between the turbines and the house and he was outside.	
		Hum heard and felt in double glazed picture window when turbines running.	
		Spent more time at shore at boat, away from house and property, for symptom relief.	

*Exposure period 5 months.

**Interviewed 6 weeks after move.

Family Table B2 (page 1 of 2)

Person
Mrs. B
Age
53
Pre-exposure health status
Good
Health history
Hysterectomy and cholecystectomy, 4 births
Previous noise exposure
Diesel fishing boat intermittently for decades
Time to onset of symptoms
Several weeks, with progression

	Pre-exposure	During exposure*	Post-exposure**
Sleep	Good	Delayed onset, repeated awakening, difficulty going back to sleep, nocturia. Ear plugs somewhat helpful.	Resolved
Headache	Rare, mild	Continuous except when left property or wind in favorable direction.	Resolved
Cognition	Normal	Concentration disturbed; confused if went on errands without list, had to return home.	Partly resolved at 6 wks, up to remembering three things without a list.
Mood	Good, hard worker, not moody.	Anxiety, guarding against irritability, upset and "in a turmoil" when symptoms worse.	Resolved
Balance/equilibrium	Normal, never carsick or seasick.	Some unsteadiness and gait change.	Resolved
Ear/hearing	Normal hearing test in 2005, no tinnitus.	Tinnitus and ear pain continuous except when left property or wind in favorable direction. Ear irrigation at clinic worsened tinnitus.	Resolved
Eye/vision	Normal with glasses	Eyes irritated, burning, runny. Ebb and flow of eye symptoms synchronous with headache and tinnitus.	Burning resolved but visual blurring noted when chemotherapy started.
Other neurological	Normal, no concussion	No change	No change
Cardiovascular	Normal including BP	Mild BP elevations 132-140/80-90	Unknown
Gastrointestinal	GER and post-tussive vomiting.	No change	Worsened with chemotherapy

Family Table B2 (page 2 of 2)

	Pre-exposure	During exposure*	Post-exposure**
Respiratory	Chronic cough secondary to GER and smoking.	Breath "short every once in a while, like [while] falling asleep, breathing wanted to catch up with something, hard to explain."	Resolved, normal breathing pattern.
Oncologic	Felt well though had undiagnosed breast cancer.	Breast cancer diagnosed. Mastectomy 4 wks before end of exposure.	Chemotherapy started.
Other		Left house repeatedly to get relief of symptoms, interrupting work and tasks.	Resolved
Machines	Refrigerator quiet	Refrigerator became loud and was replaced, but new one was also loud.	New refrigerator was moved to new house and is quiet.
	Furnace quiet	Furnace became loud. Circulator was replaced and the furnace was still loud.	

*Exposure period 5 months.

**Interviewed 6 weeks after move.

Family Table C2 (page 1 of 2)

Person
Mrs. C
Age
42
Pre-exposure health status
Good
Health history
Migraine disorder, 6 healthy term pregnancies without hypertension
Previous noise exposure
No significant
Time to onset of symptoms
Immediate when first turbines operational, with progression

	Pre-exposure	During exposure*	Post-exposure**
Sleep	Good	Delayed onset, frequent awakening, hyperalert when awakened, nocturia; "no good rest in 10 months."	Resolved including nocturia.
Headache	Migraine frequency varied, never awoke her at night; headache onset in childhood.	Headache onset day or night, 5-6 nights/wk at maximum.	Resolved, no migraines.
Cognition	Normal, very organized mother of 6 children, "ready a month in advance for birthday parties."	Disorganized; could not handle as many things at once; difficult to plan and track cooking; "I thought I was half losing my mind"	Resolved including ability to multitask.
Mood	Good, lots of energy.	Tired, anxious, irritable.	Improved, but still sadness and stress related to loss of home and living with parents.
Balance/equilibrium	Lifelong motion sensitivity in cars, boats, swings, standing on wharf seeing boats go up and down. No vertigo.	Frequent dizziness, vertigo, and nausea preceding headaches.	Resolved.

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Family Table C2 (page 2 of 2)

	Pre-exposure	During exposure*	Post-exposure**
Ear/hearing	Normal hearing, no tinnitus.	Tinnitus began when first 2 turbines operational; no change in hearing.	Hyperacusis
Eye/vision	Normal, no glasses.	Nystagmus, subjective blurring.	Persistent subjective blurring
Other neurological	Normal, no concussion.	No change	No change
Cardiovascular	Normal including BP during pregnancies and at other times.	Hypertension and episodes of tachycardia.	Persistent BP elevation 180/102, started medications. Rare palpitations.
Gastrointestinal	Normal	Frequent nausea with dizziness and headache.	Resolved
Respiratory	Normal, never smoked.	Pneumonia with pleurisy twice in first 3 months of exposure to all turbines.	Resolved
Other	Hand and foot eczema	Exacerbation	Persistent increased itching.
		• At sunset, strobe effect inside or moving shadows outside triggered dizziness, nausea, and headache. • Occasional sensation of vibration in feet and legs outside house.	Resolved

*Exposure period 15 months to all turbines, 21 months to at least 2 operating turbines. Interviewed 2 weeks before move and 18 and 21 months after move.

** Limited ongoing exposure of several hours per week when goes to house to get things, but stopped going to house by 25 months after moving.

Family Table D1 (page 1 of 3)

Person
Mr. D
Age
64
Pre-exposure health status
Disabled due to injury to back and neck in industrial accident, without paralysis
Health history
Ulcer age 61; current medications Tylenol #3, omeprazole, docuset, senecot, lovastatin
Previous noise exposure
Heavy industry age 16-37, including weaving mills, turbine and jet engine production
Time to onset of symptoms
Sleep disturbance immediate. Palpitations/tremors by 4-6 wks. Retinal stroke at 11 weeks. Diarrhea and GI bleeding by 4 months.

	Pre-exposure	During exposure*	Post-exposure**
Sleep	No sleep problems. One Tylenol with codeine at bedtime for back pain. Did not awaken or get up to urinate until morning.	Feels pulsation as soon as he lies down in bed. Frequent awakening, 6-12 per night. Nocturia 2-3 per night. "The worst sleep you ever heard of, up half the night." Gets to sleep using self-hypnosis he was taught for pain (counting backwards), but has to start at a higher number and count longer.	Sleeps well away from home, without nocturia.
Headache	Rare/mild. No migraine or sinus problems.	Not headache, not painful, but a "kind of numbness which sets over the head" [see below, Balance/equilibrium]	Does not occur away from home.
Cognition	Concentration and memory good. 2-year college degree in industrial engineering.	More difficulty remembering what he reads. In last 2-3 months "I notice a little more each time." "Once I had real fast recall, but now I have to think about things."	No information
Mood	No depression, anxiety, panic, or anger problems.	Frequent need to "calm down." Angry, including in night when awakened. "I can get real aggressive now and I never used to. If something doesn't go my way, I get real flustered, and then start with that nervousness and I have to go calm myself down." Irritable. Anxious about his own and wife's health and well-being.	When away for weekend, "you get all relaxed and all of a sudden you're back in the same thing again." "Getting away calms you down."

Family Table D1 (page 2 of 3)

	Pre-exposure	During exposure*	Post-exposure**
Balance/equilibrium	Never carsick but badly seasick once as a child. Avoided water ever after and disliked crossing bridges. No vertigo.	After retinal stroke, episodes of "numbness coming over my head. It seems to be my brain. Light-headed, not dizzy, I don't stagger. I can hear, I can talk, everything works for me properly, it's just that I get light-headed." No vertigo.	Does not occur away from home.
Ear/hearing	Some hearing loss but no difficulty understanding conversation. Skillfully differentiates machine noises in all settings. Has background tinnitus.	Background tinnitus is louder and higher, a "squeal," when turbines in operation. Drops in pitch when turbines are off and changes intensity when turbines change direction. When louder, the tinnitus interferes with hearing. No other sensations in ears.	Tinnitus at baseline when away from home.
Eye/vision	Wears glasses and has early cataracts.	Painless retinal stroke at night during sleep. Lost over half of vision in left eye. Confirmed by ophthalmologist, who talked to Mr. D about muscles squeezing off blood vessels in his eye. Normal CT.	No change
Other neurological	Normal without history of seizure or tremor.	After 16 mos: "Right arm jumps all over on its own...it just sits and bounces...hand shaking fierce just hanging onto the phone...started with feeling of satin or silk between the fingers...feels like it's wore out, like you're grabbing something real tight all the time...muscle spasms"; had nerve conduction studies [results unknown] and normal MRI of brain.	Arm calmed down during 5 days away and worsened on return.
Cardiovascular	Normal including BP, no palpitations.	Episodic tachycardia: "My heart feels like it's starting to race like crazy and I have these tremors going through my body and I was getting into a light pain on the left side of my chest." Symptoms exacerbated by nitro spray. Stress test terminated in 30 seconds. Scheduled for cardiac imaging test.	Does not occur away from home.
Gastrointestinal	Uses laxative to counteract opiate effect. Ulcer 2 years before while taking aspirin.	Stool again positive for blood; omeprazole started, endoscopy scheduled; bowels too loose or too firm.	No information.
Respiratory	Normal except smoking age 15-44, no asthma.	Pants or hyperventilates when tremor and tachycardia occur, and consciously slows his breathing when calming down.	Does not occur away from home.
Endocrinologic	No diabetes or other problem.	No change.	No change.

Family Table D1 (page 3 of 3)

	Pre-exposure	During exposure*	Post-exposure**
Rheumatologic	Persistent neck and back pain due to injury at age 37. Two Tylenol with codeine daily, rarely more. No other joint problems.	No change.	No change
Other	Spent his time outside with ponies and traveled to Florida with wife for 6 weeks in winter.	"Now I don't go outside at all." At f/u interview, the couple had not taken their next winter trip to Florida because of Mr. D's health problems.	No information.
		"When turbines get into a particular position (facing me), I get real nervous, almost like tremors going through your body...it's more like a vibration from outside...your whole body feels it, as if something was vibrating me, like sitting in a vibrating chair but my body's not moving." Occurs day or night, but not if the turbines are facing "off to the side." If outside, "I come in, sit down in my chair and try to calm myself down. After an episode like that, I'm real tired."	Does not occur away from home.
		Two months of static electric charge in yard: hair on arms would stand up when he stood in a certain area.	Static charge resolved.
		F/u interview: had bought his own sound meter, registers 50-70 dB all the time.	
Animals	Ponies well trained for riding, jumping, and pulling cart.	Riding pony refused to leave barn, go up road, or go in field over jumps. Cart pony broke into sweats, trembled, ran uncontrolled through gates and fences with cart and harness attached. Both ponies were sold 8 wks into exposure period.	No information.
	Dog had 4 litters previously and did well.	Puppies 3 days old: mother had killed one large healthy puppy; she was staying with puppies and tolerating nursing but not licking or caring for pups.	No information.

*Exposure period 6 months by first interview and 16 months at f/u interview. Information is from first interview unless otherwise noted.

**Had purchased second house but not yet moved at f/u interview; away only for weekends or short trips.

Family Table E2 (page 1 of 2)

Person
Mrs. E
Age
56
Pre-exposure health status
Fibromyalgia vs. reflex sympathetic dystrophy
Health history
4 term births, appendectomy, hysterectomy with "nerve damage" at age 38
Previous noise exposure
No significant
Time to onset of symptoms
Immediate with progression

	Pre-exposure	During exposure*	Post-exposure**
Sleep	Normal except after hysterectomy	Onset delayed up to 3 hours, multiple awakenings, nocturia (no glucosuria). At times awake all night, worse when blades facing NW.	Sleeps well, no nocturia
Headache	Rare, mild. Only one previous similar headache, when landing in a jet with nose and ears plugged from allergy.	Headache whenever turbines were generating. "In the wintertime, the strobing in the house and on property built up such pressure in my head you'd think it was going to blow off the top."	No headaches.
Cognition	Normal: retired teacher, organizes community activities	When blades facing house, could not spell, write letters, or keep her train of thought on the telephone, but was able work when blades not facing house.	Resolved; no concentration or memory difficulties.
Mood	Mild anxiety with chronic low-dose anxiolytic at bedtime	Episode of depression.	At baseline.
Balance/equilibrium	Never carsick or seasick. Vertigo twice in past, each episode 1-2 weeks.	"Lightheadedness, head kind of swimming." Less steady on feet depending on direction blades facing, especially outside	Resolved.
Ear/hearing	Normal, tested	Occasional sensation like insect crawling in ear; no tinnitus or change in hearing	Resolved.
Eye/vision	Normal, glasses for reading only	No change	No change
Other neurological	Painful right leg and abdomen ascribed to nerve damage, uses TENS unit; no concussion	Pain worse, increased use of TENS unit	Resolved when away even for short periods.
Cardiovascular	Normal including BP	"Heart synchronized to rhythm of blades." When lying on back, felt "ticking" or "pulsing" in chest in rhythm with swish of the blades. Could make it stop by getting up and moving around, but started again when she lay down. Occurred more at night. No change in BP.	Resolved.

Family Table E2 (page 2 of 2)

	Pre-exposure	During exposure*	Post-exposure**
Gastrointestinal	GER resolved with diet intervention.	Nauseated when she had a pounding headache.	Resolved.
Respiratory	Normal, never smoked. Soprano in church choir.	More coughing illnesses as opposed to URIs, one lasting 6 weeks. Lost ability to sing.	Both resolved.
Rheumatologic	Fibromyalgia; osteoarthritis in hands	Diffuse muscle aches, "thought my fibromyalgia had really flared up."	Resolved when away even for short periods
Animals	Anxious dog	Dog did not sleep, wet floor 9/10 nights	Dog dry and no longer anxious

*Exposure period 17 months.

**While away on trips of 12 days to 3 weeks and after final move 1 month before interview.

Family Table J1 (page 1of 2)

Person
Dr. J
Age
49
Pre-exposure health status
Good
Health history
Broken nose repair as teen; thyroglossal duct cyst excision as child
Previous noise exposure
Uses tractors and chain saws on property with hearing protection
Time to onset of symptoms
Immediate with progression

	Pre-exposure	During exposure*	Post-exposure**
Sleep	Long-term difficulty with returning to sleep started during medical training, had been improving	Delayed sleep onset and frequent awakening when turbines running fast; awakens with racing heart; can't get back to sleep; taking prescription sleep aid.	Improved sleep, no need for sleep aid
Headache	Infrequent sinus headache, no migraines	Bilateral temporal-parietal headaches 3-4 times a week; may follow a "jittery" episode.	No headaches
Cognition	Good; specialist physician	Difficulty with focus and mental energy after nights of poor sleep, marked concentration problem when doing accounts/bills at home.	Concentration seemed fine but demand low
Mood	Good, no history of anxiety or depression	"Jittery" episodes begin with sensation of "internal quivering" or awakening with rapid or pounding heart; gets "real anxious"; has to stop outdoor or family activities and go indoors; at night has to move to basement where the turbines cannot be heard or felt; on arriving home from work, he can judge whether symptoms will be triggered by the rotational speed of the turbines or the noise/feeling of vibration in the garage; increased irritability; taking two anti-anxiety medications.	No "jittery" episodes or anxiety when away or at work; no need for prn anxiety medication.

Family Table J1 (page 2of 2)

	Pre-exposure	During exposure*	Post-exposure**
Balance/equilibrium	Good, seasick once in life	3 episodes of transient vertigo/dizziness while in tree stands late in day	No dizziness or vertigo
Ear/hearing	Slight left hearing loss on test 10 years prior; tinnitus during sinus infections	No subjective change in hearing; occasional tinnitus outdoors when turbines spinning rapidly.	At baseline; no tinnitus
Eye/vision	Normal with glasses	Developing presbyopia (expected for age)	No change
Other neurological	Normal with mild concussion age 7	No change	No change
Cardiovascular	Normal including BP; no palpitations.	BP normal but not measured during "jittery" episodes; awakens with rapid or pounding heart and "jittery" sensations when turbines noisy.	No "jittery" episodes
Gastrointestinal	Normal without GER or nausea	Queasiness and reduced appetite in evening with onset as he arrives home from work	No nausea, appetite good
Respiratory	Normal without asthma; smoked age 18-23	No change	No change
Other	Farming, building, and hunting activities for relaxation at home	Home more stressful than work; driven inside from farming activities, picnics, playing with sons, and hunting by turbine noise provoking symptomatic episodes.	Able to relax outdoors
Animals		Horse, 5 beef cattle, ducks unaffected	

*Interviewed after 9 months of exposure. Family has not moved.

**Away for vacation for 2 weeks during the first 3 months of exposure and 10 days during the month before the interview.

Family Table J2 (page 1 of 2)

Person
Mrs. J
Age
47
Pre-exposure health status
Good
Health history
Two term births
Previous noise exposure
Aircraft during medical evacuations
Time to onset of symptoms
1-3 mos to headaches; 1-3 mos to concentration and memory problems; 4-5 mos to continuous palpitations; 6 mos to exacerbation of irritable bowel.

	Pre-exposure	During exposure*	Post-exposure**
Sleep	Slept well under any circumstances	Falls asleep easily; if awakened, can usually go back to sleep	Slept well
Headache	No headaches	Evening headache at least every 2 wks requiring ibuprofen	No headaches
Cognition	Good; acute/critical care nurse; teaches nursing at university; organized mother; no problem with focus or memory.	Noticeable trouble focusing and remembering at home; has to write down what children tell her or any item to be picked up at store; easily distracted; started vitamins and supplements	Improved memory when away but not at baseline (also less demand)
Mood	Happy, energetic, busy, "up" person	Marked decrease in energy and motivation at home; frustrated; "on edge"; feels rejuvenated at work	Felt great, lots of energy
Balance/equilibrium	Never carsick or seasick, no h/o vertigo	No change	No change
Ear/hearing	Normal, tested yearly; no tinnitus	No change, no ear symptoms	No change
Eye/vision	Normal, wears contact lenses	No change	No change
Other neurological	Normal; no concussion	No change	No change

Family Table J2 (page 2 of 2)

	Pre-exposure	During exposure*	Post-exposure**
Cardiovascular	Normal BP except during first pregnancy; dysrhythmia (trigeminy) 10/06 resolved with caffeine restriction.	Continuous palpitations began 10/07 and did not respond to caffeine restriction or trials of two medications; evaluated including electrophysiology; right ventricular focus.	Decreased frequency of palpitations
Gastrointestinal	Irritable bowel (cramping and diarrhea) since young adulthood with exacerbations before exams; normal colonoscopy x 2.	Continuous symptoms for 3 months before interview, except during week after return from vacation	Symptoms unchanged while away in tropical country
Respiratory	Normal, no asthma, never smoked	No change	No change
Other		• Feels vibration in feet/lower legs when stands still in house or barn, which feels like it is coming from vibrations in the structure; worse in barn, which is not insulated; does not feel this outside/on the ground. • Sounds like helicopter starting up or jet circling house every 3-4 seconds	

*Interviewed after 9 months of exposure. Family has not moved.

**Away for vacation for 2 weeks during the first 3 months of exposure and 10 days during the month before the interview.

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GLOSSARY

A-weighting network: see definition on p. 8.

Acute gastrointestinal infection: nausea, vomiting, abdominal pain, and diarrhea, generally self-limited and caused by a viral infection of the gastrointestinal tract.

Agoraphobia: an abnormal fear of leaving the house.

Airways: trachea, bronchi, and bronchioles, the tubular structures through which air passes to reach the air sacs or alveoli of the lungs.

Amaurosis fugax: temporary loss of vision in one eye.

Anticoagulation: use of medications such as heparin or warfarin to decrease the tendency of the blood to clot. Higher INR (international normalized ratio of prothrombin time) values, used in the monitoring of warfarin administration, indicate slower or less effective clotting.

Arthralgia: joint pain without objective signs of inflammation (see *arthritis*).

Arthritis: pain and/or stiffness in joints with accompanying objective signs of inflammation, such as redness or swelling.

Ataxia, ataxic: in reference to gait, unsteady on feet, difficulty with balance or coordination in walking, or difficulty maintaining posture, for neurologic reasons.

Asthma: intermittent and reversible respiratory difficulty caused by partial obstruction of small airways by inflammation/swelling and constriction of smooth muscle around the airways. Asthma attacks may be provoked by any kind of respiratory infection, allergic exposures, or irritant exposures.

Atrial fibrillation: an abnormal heart rhythm in which the small chambers do not pump rhythmically, but instead vibrate erratically, placing patients at risk for stroke from blood clots that can form inside the heart.

Autonomic nervous system: the involuntary part of the nervous system that regulates automatic body functions such as heart rate, blood pressure, gastrointestinal function, sweating, glandular output, pupillary reflexes, airway smooth muscle tone, and others. The autonomic system includes sensory receptors (for afferent signals or input to the central nervous system) and effector neurons (for efferent signals or output to organs). It consists of opposing sympathetic and parasympathetic networks. Sympathetic stimulation speeds the heart and readies the body for optimal "fight or flight" activity. Parasympathetic stimulation slows the heart, lowers blood pressure, and facilitates digestion.

Baroreceptors: pressure detectors, as in blood vessels or lungs.

Basilar migraine: migraine with auras representing brainstem effects, including vertigo, tinnitus, fluctuations in level of consciousness, and temporary motor deficits.

Binaural processing: brain integration of neural signals from both ears.

Bilateral: on both sides of the body.

Bone conduction: sound or vibratory stimuli reaching the inner ear via direct solid-to-solid transmission, without passing through or utilizing the tympanic membrane or middle ear ossicles.

C-weighting network: see definition on p. 8.

Caloric test: a test of semicircular canal function and the vestibulo-ocular response. In the caloric response to ice water in the external auditory canal, thermal convection induces fluid movement within the horizontal semicircular canal, creating an illusion of head movement that is reflected in eye movement via the vestibulo-ocular reflex.

Cardiac arrhythmia or **dysrhythmia**: specific types of irregular heartbeat, often occurring episodically.

Catecholamine: a class of biochemicals that function as neurotransmitters in the brain and as hormones produced by the sympathetic part of the autonomic nervous system, such as epinephrine (adrenalin), norepinephrine, and dopamine.

Central: occurring in the brain (central nervous system), as opposed to a peripheral neural receptor, effector, or organ. For example, central processing, central origin, central dysfunction.

Cerebellum, cerebellar: a posterior/inferior portion of the brain with important functions in coordination and integration of movement.

Chemotherapy: in this report, refers specifically to medications given for cancer treatment.

Cilium, cilia: actively motile, hair-like projections from epithelial cell surfaces in the airways and Eustachian tubes that beat in synchrony to move mucus out of these moist, air-filled spaces, towards the pharynx. Cilia occur on surfaces of other types of cell, including single-celled protozoa.

Circadian rhythm: a daily physiologic cycle, such as sleep and wakefulness or peaks and troughs of cortisol secretion.

Cochlea: spiral-shaped sensory organ of hearing, part of the inner ear membranous labyrinth. See p. 26.

Collagen: a protein which is the chief substance of connective tissue, cartilage, tendons, etc.

Concussion: mild brain injury produced by impact to the head resulting in brief unconsciousness, disorientation, or memory problem.

Coronary artery disease: partial obstruction or narrowing of the small arteries that supply the heart muscle.

Cortex, cortical: the outer cellular layers of the two cerebral hemispheres of the brain.

Cortisol: the major natural glucocorticoid hormone produced by the adrenal cortex in a regular daily rhythm and in response to stress, which exerts diverse effects on tissues and metabolic processes throughout the body.

Cranial vault: the space in the skull that contains the brain.

Diaphragm: the dome-shaped sheet of skeletal muscle that separates the thoracic (chest) and abdominal cavities and enables breathing.

Dysfunction: malfunction or poor functioning.

Elastin: an elastic connective tissue protein, which gives elasticity to certain structures, such as arterial walls.

Electroencephalogram (EEG): a recording of brain waves monitored in a specific fashion, used in studies of seizure disorder and sleep.

Epithelial basement membrane: a thin layer of extracellular proteins and mucopolysaccharides that lies at the base of and supports the layers of cells comprising an epithelium, such as the linings of airways, mouth, esophagus, intestine, pleura, etc.

Eustachian tube: a tube that connects the middle ear with the nasopharynx, or upper part of the throat behind the nose. It allows equalization of air pressure on either side of the tympanic membrane.

Fibromyalgia: a condition of chronic pain of muscles, ligaments, tendons of unclear origin, without inflammation.

Gastritis: inflammation of the lining of the stomach causing pain and nausea.

Gastroesophageal reflux: reflux or intrusion of acidic stomach contents into the esophagus; heartburn.

Gastrointestinal tract: stomach, small intestine, and colon or large intestine.

Glucose instability: in diabetes, fluctuating blood sugar levels that go too high or too low.

Graviceptors: neural detectors of gravity and acceleration; see definition on p. 23.

Great vessels: the large arteries and veins immediately around the heart, including the aorta, pulmonary artery, pulmonary veins, and superior and inferior vena cavae.

Hippocampus: a brain region in the medial temporal lobe critical to spatial navigation and formation of new episodic memories.

Hyperacusis: oversensitivity to sound, with normal sounds seeming painfully loud.

Hypopharynx: the lower part of the throat, just above the larynx (vocal cords).

Hypertension: high blood pressure.

Immissions: in acoustics, sound from the point of view of the person or location receiving the sound. *Emissions* in this context refers to the sound as it leaves the source.

Infrasonic: sound frequency below hearing range, generally considered to be 20 Hz or less.

In utero: in the uterus during pregnancy.

Irritable bowel syndrome: recurrent episodes of abdominal pain and diarrhea, often with alternating periods of constipation, without any pathologic or inflammatory changes in the gastrointestinal tract.

Labyrinthine organs, membranous labyrinth: the inner ear organs, including the cochlea, utricle, saccule, and semicircular canals. See *otolith organs* and *semicircular canals*, and p. 26.

Lower respiratory infection: bronchitis, pneumonia, or pneumonia with pleural effusion (pleurisy).

Lupus: systemic lupus erythematosus, a systemic inflammatory or autoimmune disease affecting the skin, joints, gastrointestinal tract, kidney, blood, and brain.

Magnetic resonance angiography (MRA): a noninvasive imaging method for examining the patency of blood vessels.

Magnetic resonance imaging (MRI): soft tissue imaging using magnetic fields, providing the most detailed images of living brain structure available. Functional magnetic resonance imaging (fMRI) quantifies blood flow to different brain structures during specific activities.

Malaise: a vague sense of not feeling well.

Mastoid: a bony structure immediately behind the ear that contains air-filled cells connected to the middle ear.

Mediastinum: the central portion of the chest or thorax between the lungs, containing the heart, great vessels, trachea, esophagus, lymph nodes, and other structures.

Mesentery: a fold of membranous tissue encasing and attaching the small intestine and other abdominal organs to the inside of the peritoneal (abdominal) cavity, also supporting blood vessels and nerves to the organs.

Microvilli: hair-like projections from epithelial cell surfaces that increase absorptive surface area, for example, in the small intestine.

Migraine: a hereditary, episodic, neurologic condition generally involving severe headaches that may be preceded by visual or other sensory phenomena such as tingling or numbness (aura), with symptoms of nausea and sensitivity to light and sound commonly accompanying headaches. A headache may be one-sided or pounding. Aura and accompanying symptoms may include vertigo, tinnitus, temporary focal weakness or paralysis, temporary loss of vision, vomiting, or loss of consciousness. Sensory sensitivities and triggers include motion, odors, a wide variety of foods (especially products of fermentation or aging, caffeine, chocolate, and varieties of plants), hormonal state, and sleep deprivation.

Migraineur: a person who gets migraines.

Myocardial infarction: heart attack, or obstructed coronary blood flow leading to death of cardiac muscle.

Neuroanatomic: referring to the anatomy of neural linkages in the brain.

Neuroendocrine: relating to cells or tissues that release hormones into the blood in response to a neural stimulus.

Night terror: a parasomnia, or sleep disturbance occurring during disordered arousal from the deeper stages of sleep, in which a person (usually a child) may scream, act afraid, say nonsensical things, or get up to do irrational or fearful things, all without memory in the morning.

Nocturia: awakening and getting up repeatedly in the night to urinate.

Nocturnal enuresis: bedwetting while asleep.

Norepinephrine: a central catecholamine neurotransmitter, sympathetic nervous system neurotransmitter, and vasoactive adrenal medullary hormone.

Nystagmus: a pattern of eye movement indicating a disordered vestibulo-ocular reflex that is often due to disordered vestibular signaling or processing, as in the caloric test.

Ocular: pertaining to the eyes.

Orbit: the eye socket or hollow space in the skull that contains the eyeball and its associated structures.

Otolith organs: the utricle and saccule, labyrinthine organs of the inner ear that detect linear acceleration, including gravity, by virtue of microscopic calcium carbonate stones or *otoconia* positioned in a protein matrix over the mechanically sensing hair cells. See p. 26.

Palpitations: irregular or pounding heart at times not expected from activity or exertion.

Panic attack: an episode of sudden intense fear out of proportion to circumstances, which may be accompanied by symptoms of dizziness, sweating, trembling, chest pain, palpitations, and the feeling of not being able to get enough breath.

Parabrachial nucleus: Pontine brain center involved in extended vestibular system influence

Parasomnia: a sleep disturbance occurring during disordered arousal from the deeper stages of sleep, such as sleep walking, sleep talking, and night terrors.

Paresthesia: tingling or "pins and needles" sensation, as when a numb extremity is waking up.

Parkinson's disease: a neurologic degenerative disease involving dopamine-producing neural tracts in the brain and affecting movement and psychiatric status.

Pericardium: the two-layered membranous sac that encloses the heart and the roots of the great vessels, in which the heart beats.

Perilymphatic fistula syndrome: see p. 30.

Pharynx: the throat.

Pleura: the outer epithelial surface of the lung and the lining of the thoracic cavity, providing low friction surfaces for lung movement.

Polyuria: excessive daily volume of urine, a typical sign of high glucose levels in diabetics.

Positron emission tomography (PET): a method of functional imaging that quantifies glucose uptake by different brain regions as a measure of activity.

Posturography: a form of balance testing that is sensitive to the vestibulo-spinal reflexes, including the influence of inner ear, visual, somatosensory, and central processing on the movements by which a subject remains balanced and upright.

Pressure equalization tube: a tube inserted through a small, surgically placed hole in the tympanic membrane after removal of middle ear fluid, to provide aeration.

Resonance: a property of sound; see pp. 7 and 25.

Retina, retinal: the light-sensing neural structure at the back of the eye.

Scotoma: temporary loss of vision in one part of the visual field.

Semicircular canals: bilateral labyrinthine organs of the inner ear that detect angular acceleration of the head by virtue of fluid shifts deflecting mechanically sensing hair cells. See p. 26 and *caloric test.*

Serotonin: a brain and gastrointestinal neurotransmitter.

Serous otitis media: viscous fluid in the middle ear (middle ear effusion) that may obstruct sound transmission, usually occurring after a series of acute ear infections.

Sequela, sequelae: a pathologic condition that develops from another pathologic condition, such as chronic middle ear fluid and hearing loss being sequelae of repeated acute ear infections.

Somatic nervous system: the sensory and motor nervous system from and to the skin, skeletal muscles, and associated tendons and ligaments, whose signals may be consciously perceived and voluntarily modified.

Somatosensory: sensory input from the skin, skeletal muscles, tendons, and ligaments.

Sonic: sound frequency in the range of human hearing.

Tachycardia: rapid heartbeat.

Taxon, taxa: a group or groups in the scientific categorization (Linnaean taxonomy) of living things.

Temporal bone: solid bone at the base of the skull, in which the labyrinthine organs lie.

Thalamus: a part of the brain involved in part in relaying sensory information to the cerebral cortex.

Tinnitus: "ringing in the ears," which may be a tonal sound, buzzing, white noise, or other types of sound heard in one or both ears. The sound itself is not present in the outside environment.

Trachea: the large central airway between the larynx (voice box) and the split or bifurcation of the right and left bronchi.

Tympanic membrane: eardrum; the layer of taut, thin tissue that separates the external auditory canal from the middle ear.

Ulcer: duodenal or gastric ulcer.

Ultrasonic: sound frequency above hearing range, generally considered to be 20,000 Hz or more.

Upper gastrointestinal symptoms: gastroesophageal reflux, gastritis, and/or ulcer.

Vasculitis: inflammation of blood vessels, which can cause restriction of blood flow.

Vasoconstriction: constriction of a blood vessel.

Vertigo: the spinning form of dizziness, in which the visual surround seems to move.

Vestibular: pertaining to the balance organs in the inner ear (utricle, saccule, and semicircular canals) or to the integrated balance system in general, as in "vestibular areas of the brain."

Visceral: pertaining to the internal organs.

Whiplash injury: an injury to the neck (cervical vertebrae) caused by abrupt acceleration or deceleration, as in an automobile accident.

ABBREVIATIONS

χ^2	chi-squared statistic or test
CT	computerized tomography
dB	decibels
dBA	decibels measured with an A-weighted filter
dBC	decibels measured with a C-weighted filter
CSF	cerebrospinal fluid
EEG	electroencephalogram
EH	endolymphatic hydrops
ft	feet
Hz	Hertz (frequency in per second or sec^{-1})
INCE	Institute of Noise Control Engineering
INR	international normalized ratio of prothrombin times (see *Glossary*: anticoagulation)
km	kilometers (1000 m)
m	meters
mcg	micrograms
mg	milligrams
mi	miles
MRA	magnetic resonance angiography
MRI	magnetic resonance imaging
MW	megawatts
p	when used in the context of a statistical test, p means probability that the compared distributions are no different from each other
P.E.	professional engineer
PET	positron emission tomography
PTSD	post-traumatic stress disorder

VVVD visceral vibratory vestibular disturbance (defined in this paper, p. 11)

WHO World Health Organization

WTS Wind Turbine Syndrome

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PERSONAL

Place of birth: Stamford, CT
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Married with two adult stepchildren

EDUCATION AND TRAINING

Education

1991	M.D.	The Johns Hopkins University School of Medicine
1985	Ph.D.	Princeton University (Ecology, Evolution, and Behavior)
1981	M.A.	Princeton University (Ecology, Evolution, and Behavior)
1977	B.A.	Yale University (cum laude)
1973		Milton Academy, Milton, Mass.
1970		New Canaan Country School, Conn.

Post-Doctoral Training

1992 to 94	Pediatrics	Dartmouth-Hitchcock Medical Center, Lebanon, NH
1991 to 92	Pediatrics	Children's National Medical Center, Washington, DC
1985 to 86	Ornithology	American Museum of Natural History, New York, NY

Licensure and Certification

1997	Licensed Physician, New York
1997	Licensed Physician, New Hampshire (expired)
1995	Pediatric Advanced Life Support (recertified 2002)
1994	Diplomate, American Board of Pediatrics (recertified 2008, expires 2015)
1994	Licensed Physician, Alaska (expired)
1994	DEA Registration
1994	Advanced Trauma Life Support Provider (expired)

1994 Advanced Cardiac Life Support Provider (expired)
1992 Neonatal Advanced Life Support Provider (recertified 2003)

Continuing Education

2008 Intermediate Training in the Psychological Treatment of Children with Trauma-Attachment Problems - Daniel A. Hughes, Ph.D. (32 hours)
2007 Training in the Psychological Treatment of Children with Trauma-Attachment Problems - Daniel A. Hughes, Ph.D. (32 hours)
2006 Workshop in Basic Pediatric Hypnosis (20 hours)
2006 Introductory Theraplay Training (27 hours)
2005 Psychiatry: Comprehensive Update and Board Preparation (Harvard, 51 hours)
2005 ADHD Across the Life Span (Harvard, 22 hours)
2004 Gesell Developmental Evaluation, Anthony Malone, M.D., Latham, NY (6 days)
2002 Promoting Student Success (Melvin Levine, M.D., U. of N. Carolina, 20.5 hours)
2002 Psychiatric Neuroscience Home Study Course (Harvard, 16.5 hours)
2000 Child and Adolescent Psychopharmacology (Harvard, 20 hours)
1998 Clinical Diagnosis and Treatment of Fetal Alcohol Syndrome (7.5 hours)
1997 Pediatric and Adolescent Gynecology (Harvard, 14 hours)

PROFESSIONAL APPOINTMENTS

Hospital or Affiliated Institution Appointments

2004 to Consulting Pediatrician Alice Hyde Medical Center, Malone, NY
2000 to 03 Senior Attending in Pediatrics Bassett Healthcare, Cooperstown, NY
1997 to 00 Attending Pediatrician Alice Hyde Medical Center, Malone, NY
1995 to 96 Chief of Pediatrics Yukon-Kuskokwim Delta Regional Hospital, Bethel, AK (Yup'ik Eskimo)
1994 to 95 Staff Pediatrician Yukon-Kuskokwim Delta Regional Hospital, Bethel, AK

Other Professional Positions

1998 to 00 Private Practice (Solo) Pediatrics Malone, NY
1997 to 00 Staff Pediatrician St. Regis Mohawk Health Services, Hogansburg, NY
1997 to 98 Staff Pediatrician North Country Children's Clinic, Malone, NY

Academic Appointments

2000 to 03 Assistant Clinical Professor of Pediatrics Columbia University College of Physicians and Surgeons
1980 to 85 Teaching Assistant Princeton University
1978 Teacher Children's School of Science, Woods Hole, MA
1977 to 78 Research Assistant Yale University

LANGUAGES SPOKEN Spanish, French

AWARDS AND HONORS

1984 National Science Foundation Dissertation Grant (Princeton)
1979 to 82 National Science Foundation Predoctoral Fellowship (Princeton)
1979, 80 Dunlop Prize, Biology Department, Princeton University

1981 to 83	Research grants from the National Academy of Sciences, American Museum of Natural History, American Ornithologists' Union, and others
1973	National Merit Scholar to Yale University

MAJOR ADMINISTRATIVE RESPONSIBILITIES

1995 to 96	Chief of Pediatrics Yukon-Kuskokwim Delta Regional Hospital, Bethel, AK

PROFESSIONAL SOCIETY INVOLVEMENT

1997 to	American Academy of Pediatrics Fellow
2000 to	Medical Society of the State of New York
2006 to	Franklin County Medical Society
2000 to 03	Otsego County Medical Society

COMMUNITY SERVICE

1998 to 00	Physician member, Child Abuse Response Team, Franklin County, NY
1994 to 96	Physician member, Child Abuse Response Team, Yukon-Kuskokwim Delta, AK

GRAND ROUNDS

May 1994	"Infectious Diseases in Yup'ik Eskimos" at Dartmouth-Hitchcock Medical Center (Lebanon, NH)
May 2001	"Vaccinations: The Debate" at Bassett Healthcare (Cooperstown, NY)
March 2002	"Evaluation of Children and Adolescents with Behavior and Learning Problems" at Bassett Healthcare (Cooperstown, NY)
April 2002	"Vaccinations: An Overview for Family Practitioners" at Bassett Hospital of Schoharie County (Cobleskill, NY)
Feb 2003	"A Neurodevelopmental Approach to ADHD" at Bassett Healthcare (Cooperstown, NY)

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9/23/06	ADHD: Older Children: Mental Energy and Consistency
10/7/06	ADHD: In One Ear and Out the Other (Processing Controls)
10/23/06	What Elephants Teach Us about Children
11/4/06	ADHD: Look Before You Leap (Production Controls)
11/18/06	Mapping the World onto the Brain: Neurological Templates for Learning
12/2/06	Childhood Adverse Experiences and Long-Term Health (ACE Study)
12/16/06	Autism from the Inside (Temple Grandin)
1/7/07	Mirror Neurons and Autism
1/20/06	Autism, Asperger's, and Non-Verbal Learning Disabilities
2/3/07	Concussions: Short- and Long-Term Effects
2/17/03	Play + Therapy = Theraplay
3/3/07	Sick Of Poverty: Poverty, Stress, and Health
3/17/07	TV, Video Games, and Kids
4/3/07	Punished by Rewards: Research on Behaviorism
4/21/07	The Genius of Inner Motivation
5/12/07	Warbler Wave: Healing and Nature
5/26/07	Plan B: Collaborative Problem Solving

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6/9/07 Try Collaborative Problem Solving

Wind energy

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